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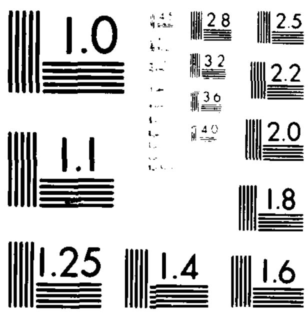

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CONTRASTS IN NAVAL AND LAND WARFARE; THEIR IMPACT ON COMBAT MODELING

KFR 374-82

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This final report gives the results of an effort to adapt an abstract "theory of combat" architecture which was developed for land warfare to the sea control aspects of naval warfare. The differences between the two forms of warfare are discussed, in terms of the applicability of the Principles of War, the geophysical and operational environments involved and the objectives and modes of combat. The differences in the two warfare

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arenas are then used to identify the different approaches required in combat modeling to achieve adequate fidelity in simulations for varied applications.

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INTRODUCTION

Models of combat are widely used, at many levels of the defense establishment, to assist decision-making on force structure, resource allocation and weapons selection. The validity and utility of the models for this usage depend, in part, on how well they represent the trends in outcomes of battles as a function of changes in the resources devoted to them. The quality of the representation depends, in turn, on two factors: the detailed input data, such as kill probabilities, and the logical structure of the model vis a vis the structure of combat. The input data can be improved through field trials and analysis. The validity of the logical structure of the model as a representation of battle is far harder to assess and perhaps impossible to prove. A beginning has been made under the rubric of the development of a "theory of combat". Such progress as has been made is limited to land battles involving army units with tactical air support. The purpose of the modest effort reported here was to explore the degree to which the understandings of land battles and the associated models can be transferred or applied to naval warfare.

The research was based on a specific stratification of combat modeling that evolved from a study of ground/air models and simulations of conflict at the theater-level.[1] The study was undertaken to place in perspective the results of a theater-level gaming and analysis workshop, which was convened in September, 1977 in Leesburg, Virginia[2] under the sponsorship of the Mathematical and Information Sciences Division of the Office of Naval Research. This workshop addressed a host of issues associated with the development, support and uses of large-scale combat simulations in the Department of Defense. In the subsequent analysis reported in Reference 2, it was shown that the <u>funda-</u>

mental difficulty in the modeling of combat was the "open-loop" nature of the relationship between attempts to apply quantitative methods to the study of war and the experimental evidence provided by actual combat, quite unlike the situation that attended the birth of Operations Research during World War II. Thus, though we are engaged in building models, we have no "laboratory of war" in which model verisimilitude with respect to actual combat can be established with confidence. In short, we have inadequate understanding of the "phenomenology of war" or a "theory of combat" to guide us in our modeling endeavors.

There appears to be a number of approaches to developing a "theory of combat", all of them based on the availability of appropriate historical or experimental combat data. None, however, can yet chart a clear course to a solution, nor for that matter, does there exist a consensus as to the form the problem solution should take. One approach to combat theory development that has received considerable attention focuses on an idealized structure for the process modeling of combat phenomena. This approach derives from the modeling research reported in Reference 1 and involves the breakdown of large-scale simulations of combat into a minimal set of basic components that are both necessary and sufficient to define uniquely both the scope and the proper structure required of a modeling endeavor. As demonstrated in Reference 1, the accommodation of all these basic components constitutes a goal that is not attained in current simulation models. Nevertheless, the approach seeks to establish a dynamic structure of the key activities and action agents that comprise combat in any and all of its forms. The separate elements of this dynamic structure can then be subjected to piecemeal verification and elaboration through the use of historical or experimental data. Within the spirit of this approach, a verified model in effect becomes an expression of a combat theory.

The combat theory developments reviewed above have so far been concentrated in the area of land warfare. It is only natural that the question of the concept of a unified combat theory be raised. In other words, having determined a structure that appears valid for decomposition of models of land warfare into fundamental components, to what extent does this structure really accommodate to other forms of warfare, such as naval and air (exclusive of ground support) warfare? In seeking an answer to this question, we are not only involved with an approach to combat theory, as described above, but also with what might be termed a "theory of modeling" or more explicitly, the derivation of structural specifications applicable to models of all forms of combat. In line with this seemingly natural relationship between modeling and combat theory, the specific objectives of this paper are two-fold. One is to postulate the dimensions and architecture of a unified combat structure as part of combat theory development. The other is to derive specifications for modeling of the sea control aspect of naval warfare in accordance with the methods developed in Reference 1 for ground/air warfare.

The method for transforming modeling specifications for any one type of warfare into those for another first involves consideration of contrasts ~~in the~~ following:

- The broad warfare missions and objectives for both cases
- The combat environments
- The organization of combat and support forces
- The equipment and weaponry used
- The tactics and doctrine that govern operations.

Using the form of unified combat structure postulated, similarities or differences in all the above factors can be evaluated and compared as to their impact on combat modeling requirements.

In the following sections of this paper, we will first compare the basic missions of land and naval forces (restricting our attention to the naval mission of sea control*). We will then examine the comparative applicability of the Principles of War to both land and naval warfare. Next, we will investigate the differences in the geophysical environments for each type of warfare and then trace how the combined factors of mission and environment, shape the differing forces, weapons and operations concepts. The general implications of these comparisons for the modeling of land and sea warfare will be discussed.

The remainder of the paper presents a fundamental concept for the modeling of all forms of warfare. This will be discussed in the context of missions, environments, force structures and operational concepts to identify in greater detail the similarities and differences in requirements for land and naval combat modeling. Fundamental difficulties inherent in the modeling of both types of warfare will be addressed.

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* The four broad missions of naval forces are generally recognized as: strategic deterrence, sea control, projection of power ashore, crisis control.

COMPARISON OF MISSIONS

The basic missions and objectives of land forces* and sea control forces are more alike than different. Yet, there are certain fundamental differences in the missions that derive from the nature of the two realms and from long-standing, universally accepted political traditions. The differences lead modeling efforts for sea control combat and land combat along apparently different paths although the basic problems and solutions are much the same.

The mission similarities rest on the common end objective of exercising control over geographical areas of interest. In formal terms, control of sea areas is exercised through seapower**, with sea control forces as the primary agent. Control of land areas is similarly exercised through landpower***, with land forces, together with supporting air, as the principal agents. The means of exercising control for both land forces and sea control forces is superior military force that either is perceived by both sides to be able to destroy or neutralize adversary forces or, if contested in conflict, does in fact succeed in the objective of destroying or neutralizing. Thus,

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* In the context used herein, land forces include air units and amphibious units that are employed in support of land force missions.

** Seapower is defined as the power to control the seas by ensuring free use of sea areas and contiguous air space and by denying, if necessary, their use to an enemy.

*** Landpower is defined as the power to exercise direct, continuous, and comprehensive control over the land, over its resources, and over its peoples (Department of the Army, Field Manual FM 100-5, Field Service Regulations - Operations, February, 1962).

success in carrying out the basic mission of control rests, aside from political constraints, on potential or realized dominance of forces in the area concerned, whether at sea or on land. It follows that the ultimate measure of effectiveness of sea control forces and of land forces is fundamentally the same: the extent that each can effectuate control over its assigned realm.

The differences in land force and sea control force missions rest on the differences in land and sea operating environments and in accepted political and social rules that pertain to each environment. The differences substantially modify the methods by which sea control and land forces execute their missions and the nature of the control they exert. In summary these differences are as follows:

- The most basic difference in operating environment is that land areas are inhabited by humans and provide the lodgement for their institutions and homes, whereas sea areas are devoid of permanent human population and institutions. Control of land areas predominantly entails control of the resident peoples together with their man-made works, although there are cases in which control of strategically important geography can itself be the primary objective (such as in the case of a key island or land bordering an important strait). The fact that land combat must normally be conducted in the midst of people and their facilities is a complicating factor in the extreme, one that can have a profound influence on the manner of carrying out land combat. The complications may take many forms, among them restraint to avoid collateral civil damage and loss of noncombatant lives; impedance of military operations by refugees; and interference by dissidents. These complications are virtually absent from sea control combat.

- A second difference between the missions assigned to land forces and sea control forces stems from the internationally accepted political and social rules that apply to land and sea areas. Land areas are universally under the sovereignty of one nation

or another* and a primary aspect of the control mission of land forces is to protect the sovereignty of the home country. Under long-accepted international law, land forces are not free during times of peace to transgress into foreign land areas unless by invitation of the governing powers (legally constituted or de facto) of those land areas. Violation of this rule is regarded as an act of aggression or war (although unusual circumstances may dictate that the violation not be challenged directly by the force in opposition). In contrast, the laws of nations have placed the high seas outside the sovereignty of national jurisdictions. Beyond sovereign coastal zones, the ocean areas have, in peacetime, been free to the movement of all vessels and aircraft, including military forces as well as civil transport. Naval and air forces of potential adversaries, unlike their land forces, commonly mingle, sometimes even during naval maneuvers. Despite current international law discussion concerning national right to economic exploitation of marine and sea bed resources, freedom of passage on the high seas can be expected to remain an accepted right of all except those engaging in piracy and illegal actions. Thus sea control forces cannot exercise the same sort of control during normal times of peace that land forces can, by virtue of the unquestioned right to maintain sovereignty inviolate. Control at sea in peacetime is latent, resting on a mutually perceived dominance of superior, ready forces.

- Related to the preceeding is another key difference. By virtue of the concept of sovereignty, nations exercise full authority over the domain that is their recognized bounded territory, including all the people and resources within. In effect, nations control through possession of land and all it contains. Therefore, land forces, as the instrument of landpower, provide the means to ensure continuing possession - and thus control -

* There are rare and usually transitory exceptions in which joint sovereignty or protectorate rule has been applied to some land areas.

through their physical presence on a nation's territory. In addition, in conflicts between states, land forces can be called upon to extend control to foreign territories by seizing and occupying land areas. Thus, taking and holding additional territory can be an objective of land forces, with the aim of extending sovereignty or at least exercising temporary control. Sea control forces, on the other hand, fulfill their control mission not by occupying and holding, but through the movement and positioning of mobile forces in a manner to safeguard friendly access to sea areas and, during hostilities, to deny enemy access. No issue of ownership or possession is involved, nor is there occupation or holding of areas in the same sense as is basic to land warfare.

- Following directly from the above, a fourth difference in sea control and land force missions involves possession and control of natural resources. For land forces, protection or acquisition of natural resources is normally an important aspect of territorial occupation, and often it is a primary mission. Oil and natural gas obviously are critical resources, and the list extends to a great variety of other natural assets. The sea control mission has not ordinarily been concerned with natural resources as a critical factor. Exceptions have involved fishing rights within territorial waters or within claimed economic exploitation zones. These have rarely been of overriding import. On the other hand, increasing interest in sea-bed mineral exploitation, at present aimed predominantly at oil and natural gas resources but in the future almost certainly extending to many other commodities, will add control of sea-based natural resources as a significant aspect of the sea control mission. The current forum for exploring this issue, the extended diplomatic negotiations on the Law of the Sea treaty will, if consummated, undoubtedly lead to additional complexities in the sea control mission, and even if the treaty is not finally effectuated, the factors that have given rise to the negotiations will still be at play. Nevertheless, despite the possibility that some limited degree of national jurisdiction over (or "ownership" of) ocean floors may develop, naval forces are likely for some time to carry out their control mission for such resources in the same mobile manner as for sea areas at large.

To summarize, the basic mission of land forces and of sea control forces, when viewed in light of the end objective sought, is the same: to exercise control in the name of a nation (or an alliance) over certain geographical areas. In both cases the means to exert control is superior military power sufficient to dominate adversaries if tested in conflict. In both cases the domination of adversary forces in war may be achieved by destroying or by neutralizing opposing forces.

Underneath the parallelism of basic mission and means, there are significant mission differences arising from the political and physical environments in which land and sea control combat are waged. Foremost is the presence of people and their man-created materiality in the former case and their virtual absence in the latter. This factor exerts an extraordinary impact on land combat missions that is not paralleled in sea control combat. A second difference is the world-wide political concept of sovereignty over land areas, and hence of continuous possession and control, in contrast to the accepted concept of freedom of the seas. Because of this, land forces normally carry out the mission of control through occupying and holding land (or sometimes by the threat to do so), whereas the missions of sea control forces do not involve possession and ownership of sea areas and hence must accommodate free passage of neutral shipping even during hostilities. In further extension of the point, sea control forces are not significantly involved in the protection or acquisition of natural resources, while this is an important factor influencing land force missions.

All these differences markedly affect the <u>particulars</u> of missions assigned to land and sea control forces. Yet it is well to keep sight of the commonality in mission and means at the most basic level, for this, in the end, is the most fundamental measure of effectiveness for which combat model results must help in providing values.

COMPARATIVE APPLICABILITY OF PRINCIPLES OF WARFARE

Simulation models of combat vary widely in the way in which the command and control of forces is represented. In some, provision is made for experienced officers to intervene at intervals to be sure that forces are applied adaptively as force structures, objectives, and systems are varied. In the majority, the simulation proceeds in a "black box". It is therefore necessary to assess whether the forces being simulated follow sensible or, at least, acceptable courses of action. The broadest precepts defining such courses are the so-called Principles of War and these serve as a touchstone for assessing the adequacy of command and control modules in large-scale combat simulations.

The Princples of Warfare have evolved over several centuries. There is no single, universally accepted set of such princples, nor any one form in which they are expounded. Nevertheless, the versions put forward by the most widely recognized authorities show remarkably little variation in basic content. However, these authorities have explicitly addressed only land combat. Such theoreticians of naval warfare as Alfred Thayer Mahan refer to fundamental principles but do not consolidate them into cohesive sets. In the following paragraphs, we explore the relevance to naval warfare of the Principles of Warfare as derived for land combat.

The set of principles stated in the now-superceded Department of the Army basic doctrinal manual, FM 100-5, Field Service Regulations-Operations, dated February 1962*, has been taken as

* The current version of FM-100-5, dated July 1976, does not include an explicit list of the principles of warfare. As has been stated by Army authorities, however, the principles still govern the doctrine set forth and can be inferred from many passages in the manual. There are some who object that the reduced emphasis implied does in fact constitute a partial shift from some of the principles of the earlier manual.

the most useful compilation of principles for comparing land and sea control warfare. Basic Soviet writings on the principles of warfare are in general agreement with this set, although the specific contextual language and form diverge. The writings of Mahan have been compared with the FM 100-5 principles to ascertain areas of commonality or difference. While this comparison did not indicate a close fit in language, no disagreement of principles was found.

More useful than a comparison of Mahan with FM 100-5 is a consideration of the nature of sea control combat operations in light of the principles of war as applied to land warfare in the earlier versions of FM 100-5. As should be expected, this consideration affirms that the Army's statement of principles of war can be applied equally as well to naval warfare. The nine principles listed in FM 100-5 can (in abbreviated form) be readily paraphrased without substantive change into naval war precepts as follows*:

> <u>Principle of the Objective</u>. Every naval operation must be directed toward a clearly defined, decisive and attainable objective. The ultimate naval objective in war is the destruction of enemy naval forces and, in conjunction with land and air forces, of all the enemy's armed forces and his will to fight. The selection of an objective for each operation is based upon consideration of the means available, the enemy, and the area of operation.
>
> <u>Principle of the Offensive</u>. Offensive action is necessary to achieve decisive results and to maintain freedom of action. The defensive may be forced on the commander, but it should be deliberately adopted only as a temporary expedient.
>
> <u>Principle of Mass</u>. Superior naval power must be concentrated at the critical time and place for a decisive purpose. Proper application of the principle of mass, in conjunction with the other principles of

* Of the nine principles listed, Mahan explicitly states principles that are reasonable parallels to the first six.

war, may permit numerically inferior naval forces to achieve decisive combat superiority.

Principle of Economy of Force. Skillful and prudent use of combat power will enable the commander to accomplish the mission with minimum expenditure of naval resources. This principle does not imply husbanding, but rather the measured allocation of available combat power to the primary task as well as secondary tasks in order to insure sufficient combat power at the point of decision.

Principle of Maneuver. Extensive maneuver of naval forces is an essential ingredient of combat power and a prime attribute of naval forces. The object of maneuver is to place the enemy at a relative disadvantage and thus achieve results which would otherwise be more costly in men and materiel.

Principle of Security. Security is essential to the preservation of naval combat power. Security is achieved by preventing surprise, preserving freedom of action, and denying the enemy information of friendly forces.

Principle of Unity of Command. The decisive application of full naval power requires unity of command. Unity of command obtains unity of effort by the coordinated action of all forces toward a common goal.

Principle of Surprise. Surprise can decisively shift the balance of combat power. By surprise, success out of proportion to the effort expended may be obtained. Factors contributing to surprise include speed, deception, cover, application of unexpected combat power, effective intelligence and counterintelligence, communication and electronic security, and variations in tactics and methods of operation.

Principle of Simplicity. Simplicity contributes to successful operations. Direct, simple plans and clear, concise orders minimize misunderstanding and confusion.

The applicability of these principles of war in common to both land and naval warfare is quite natural and logical, given their broad character. The specific tactics, materiel, and time-space factors for applying the principles will, of course, result in countless differences in how land and sea control warfare models reflect observance of the principles. The crucial point

is that models of both land and sea combat should be able to simulate the combat actions that naturally follow from observing the principles, or else their inability to do so must be explicitly accounted for in explaining model outcomes.

For example, the principles of mass and of economy of force state the value of applying critical amounts of force in certain key areas at the expense of other areas, the result being a magnification of combat power effectiveness compared to a uniform application of available force at all points. These are principles of such import as to appear to require combat models to be able to simulate the kind of actions that any commander would take in their furtherance. Similarly, the principle of surprise has been shown time and again to have such a strong impact on combat outcomes that simulation of its effect (though inordinately difficult to do accurately) is important to realism in modeling. Yet, despite the unquestioned importance of the principles of mass, economy of force, and surprise to combat outcomes, the shortcomings of many land warfare models in this respect are well known. With regard to naval warfare models, since the principles of mass and economy of force seem to be less explicitly promulgated in naval doctrine than in land war doctrine, it may be less obvious that naval warfare models which do not permit the play of these principles also are deficient.

Obviously there are state-of-the-art and other practical limitations on the current ability to minimize these basic deficiencies in modeling. For the present, the point to be made is that the principles of war cited above (or any corresponding list derived from other authoritative sources) represent matters of fundamental importance to both sea control and land combat outcomes and hence should be reflected, preferably in the models themselves, or alternatively in the interpretation of model results.

CONTRASTS IN THE PHYSICAL ENVIRONMENT FOR LAND AND NAVAL WARFARE

The most obvious factor affecting the conduct of differing categories of warfare (land, sea, air) is that of associated geophysical environment. The fundamental effects on warfare of widely differing environments, while all-pervasive in influencing the design of weapons, forces and concepts of operations, are generally taken for granted. It may, however, be useful to reflect on how warfare, and hence the modeling of warfare, is shaped by the global medium in which the fighting occurs.

Land warfare, albeit with air and amphibious support, takes place, in the main, on or close to the surface of the earth's land masses. The bulk of surface forces, whether operating on land, or at the land/sea interface (in the amphibious mode) are largely constrained to action in two dimensions. The additions to land warfare of attack by aircraft, airborne forces, and most recently, heliborne forces add a third dimension to force movement. Aircraft and space vehicles provide important third dimension platforms for sensing (and potentially for new weapon systems); but the decisive maneuvers and actions remain on the land surface itself.

The presence of terrain features, vegetation and man-made structures impact on the conduct of ground operations in the following ways:

- They strongly affect the movement of military forces, at times impeding and channeling them, at other times facilitating rapid or broad-front movement.
- They affect line-of-sight, generally interfering with or sometimes aiding observation, target acquisition, other sensing activities, and the application of firepower.
- They provide, conversely, means for cover, concealment, protection, housing and storage for forces in the combat area.

Additionally, the presence of indigenous populations (in situ or on the move) in war zones can interfere in many ways with the conduct of military operations.

Naval warfare (restricting our attention to sea control) is concerned with military activities in three media: in the air, on the ocean's surface and beneath the seas. Surface operations at sea are kinematically similar to those conducted by ground forces, with the sharp distinction that in the former instance there exist none of the impediments (and advantages) associated with terrain and man-made features of the land mass. Except for varying sea state (whose adverse effects on shipborne sensing and weapons delivery can be largely overcome by the use of space reference and stabilization devices), the ocean's surface is quite uniform and featureless. It is generally the earth's curvature that limits the range of many shipborne sensing devices and the weapons that depend on such devices for targeting and guidance information. Similarly, air operations at sea are in most respects environmentally similar to those conducted over land except that in open-ocean, air-to-surface operations, there is a total absence of the complications associated with land mass terrain, vegetation and populations.

A truly different twist - the negative third dimension - added in naval warfare is that of undersea operations. Here in a medium that is more dense than air by roughly three orders of magnitude, vehicles are employed that enjoy the same freedom of motion in three dimensions as do aircraft. Thus, we can look upon naval warfare as a set of surface operations, in two dimensions, sandwiched between three-dimensional operations above and below the surface. Ground warfare, (with supporting air), on the other hand, can be characterized as an open-face sandwich, lacking the equivalent of underwater operations.*

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* This is not to deny the use, on rare occasions in land warfare, of extensive tunneling operations and the deep mining of enemy positions and installations.

To expand this comparison, it is useful to consider the variety of intra- and intermedia operations that occur in land and sea warfare. A list of such operations is shown in Table I. The table reflects all combinations and permutations of air, surface and subsurface media taken two at a time. There are more than twice as many types of operations that must be considered in modeling naval, as compared with land, warfare.

Intuitively, one might expect this fundamental difference to work in favor of reduced complexity in modeling land warfare. Comment is reserved at this point, however, on the relative difficulties in modeling, for there can be complications in land warfare that offset the mere difference in variety of operations types to be modeled.

The relatively strong target-to-background contrast of naval surface targets together with the height afforded by airborne and space sensor platforms, and the use of over-the-horizon radar techniques (OTHR) allows for long range detection of naval air and surface targets and the correspondingly greater capability to engage at longer ranges in naval than in land warfare. There are, of course, long range weapons used in land combat but because of target acquisition difficulties, most are employed against targets that are fixed or move infrequently. Also, naval targets in sea control combat (aircraft, surface ships, submarines and missiles) are discrete, mobile targets of high value. In modeling naval combat, the above factors would tend to drive the process toward accountability for all targets and for every major weapon launched, since the numbers are manageable and each has significant potential impact on the engagement outcome.

In land warfare, the modeling of the environmental effects of terrain and other factors on systems and operations, as troublesome as this may be, is perhaps more than matched in difficulty in modeling the complexities of underwater environmental effects on vehicles, weapons and sensors in undersea operations. On the other hand, the environment is decidedly less complex for

Table I

Types of Intra- and Intermedia Operations in Land and Sea Warfare

	Category of Warfare	
Medium	Land	Sea
Air	Air-to-Air Air-to-Ground	Air-to-Air Air-to-Surface Air-to-Underwater
Surface	Ground-to-Ground Ground-to-Air	Surface-to-Surface Surface-to-Air Surface-to-Underwater
Subsurface		Underwater-to-Underwater Underwater-to-Surface Underwater-to-Air*

* An emerging concept, rather than an established one, beset with considerable difficulties.

modeling of naval surface operations than it is for modeling ground operations.

The factors of weather and climate, though infrequently modeled, would not appear to have more significant effect on one type of warfare than on the other. The effects of adverse weather and harsh climates will generally inhibit combat and slow its pace. Foul weather at sea can bring carrier-based air operations to a halt and sharply reduce the speed of advance of a naval battle group. On land, it can enmire mechanized forces and seriously disrupt target engagement. In the air, it can greatly reduce both sortie rates and the effectiveness per sortie. Submarines, of all land, air, and sea combat vehicles, appear to be the least affected by weather and climate.

Combat and support systems for both types of warfare are generally built to specifications intended to limit performance degradation under weather and climatic extremes. Thus one is hard pressed to identify the existence of sharp differences in climate and weather effects on <u>weapon systems'</u> performance in land and sea environments. The major impact is on <u>operations</u> - generally causing their curtailment or degradation.

The most significant environmental factors that lead to fundamental differences between the conduct of warfare on land and the sea are geographical and geopolitical. The oceans, uninhabited as they are, cover seventy percent of the earth's surface. They encompass what continue to be the major lanes of transport between the land masses of the world for most of the world's natural resources and the goods produced by its populations. To control such vast areas or even portions of them in naval warfare by threat or use of force calls for the employment of ships, with their mobility, clustered in a manner to defend themselves most effectively and to concentrate their firepower in the delivery of offensive weapons. These mobile groups, while not capable of the greatest speeds known, can still, in time, cover vast ocean areas. In ground warfare, armies are arrayed

against each other along largely discernible, integral lines and in the simplest of terms, it is the objective of each side in any conflict to penetrate or drive this line of combat back into enemy territory as far and as fast as possible, occupying and "possessing" all newly acquired territory in the advance. Non-combatant populations in the way of this process either flee or are absorbed and controlled by the intruders. Thus, ground warfare tends to be more tightly integrated, more uniformly distributed as to activity, and more sharply contained in its totality than is the case in naval warfare.

In the following section, by combining considerations of mission and physical environment with a broad definition of threatening forces and their strategies, we will derive a picture of the operations environments for both land and sea warfare.

CONTRASTS IN OPERATIONS ENVIRONMENTS FOR LAND AND SEA WARFARE

General

In discussing operations environments in this section, we will attempt to relate, on the basis of fundamental missions:

- The physical environment in which forces must operate and the broad nature of the military threat to the nation and its allies that must be deterred or countered;

- The ways land and sea forces are configured; and

- The ways in which they operate.

No attempt is made to pass judgement on the adequacy or "correctness" of force configurations or how they are employed - for one must grant the possible existence of alternative concepts that might afford greater combat effectiveness. Our intention is rather to identify, in the aggregate, the differences in the nature of force structures and operations as they presently exist for the conduct of war on land and on the sea so that the impact of these differences on combat modeling can be further examined.

To review briefly, we have ascertained that the force missions in land and naval warfare are basically the same; that of attaining control over certain areas of the land mass and sea domains. The manner of attaining this control, however, is fundamentally different in both cases for reasons environmental and geopolitical. However, in both land and sea warfare, the exercise of control is generally achieved by neutralizing or destroying an opponent's forces and hence, destroying his will to fight. This, in land warfare, is ultimately achieved by the physical seizure and occupation of the seat of government which generally occurs only after a progressive invasion of the enemy's homeland. In such situations, the direct destruction of enemy forces is incidental and in a sense subordinate to the seizure of territory.

In naval warfare, control over large ocean areas hinges on the mobility of naval forces and directly on the exclusion of opposing naval and air forces from the area. Under these circumstances, such exclusion is synonymous with control and is achieved by out and out destruction of enemy naval and air units or by the neutralization of units through deterrence or by barrier and blockade operations.

One can evaluate the degree of success in achieving control of the sea by considering it as a closed operation or as an end in itself. However, the ultimate significance of achieving sea control, or more specifically, how it is achieved, can only be measured in terms of the outcome of those activities (military or otherwise) that are supported by the sea war*. Thus, the complete and total evaluation of sea control as a military mission must ultimately involve consideration of the outcome of the land activity that the mission purports to sustain, for it is on land that the ultimate objective in war - an opponent's center of government and all that it controls - is established and functions.

In land warfare, there are more options available for the neutralization of enemy forces than are to be found in naval warfare: breakthroughs and breakouts, encirclements, outflanking maneuvers, deep interdiction, suppressive fires and the exercise of psychological warfare, to name a few. Non-combatants are also vulnerable in the land struggle to break a nation's will to fight. Few if any of these neutralization techniques have counterparts in naval warfare where it is more often necessary to engage in direct attrition in order to achieve sanitization of an ocean area.

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* A particular concept of sea war concerns conflict wholly confined to the ocean areas for the control of supply lanes or maritime choke points. Initially, at least, no land combat is involved.

The Threat

In all of the preceding discussion, a military threat to friendly forces has been implied. It is appropriate at this point to consider briefly the general nature of this threat.

Since the termination of World War II, the size and aggressive posture of the military forces of the Soviet Union and the satellite countries (known as the Warsaw Pact nations) have been perceived as a major threat to the security of the free world and the United States. In addition, there are widely-scattered governments in Asia, Africa and in Central and South America that have been, in varying degrees, sympathetic to Soviet ideology and, accordingly, recipients of Soviet military aid. This exposes the U.S. and its allies to potential diplomatic, economic and military crises, largely at times and places orchestrated by their opponents.

Lending substance to free world concerns about Soviet intentions is the existence of a large standing Red Army of some two million men, augmented by forces of the allied Warsaw Pact nations. This army is considered to be highly mechanized, well trained and well disciplined. Since the rapid Soviet advances into Central Europe that marked the closing phases in the West of World War II, there has been pronounced doctrinal emphasis in the Soviet army on lightning wars of movement, protracted conflict of high intensity and the use of a full range of weaponry extending from the conventional to tactical nuclear and chemical munitions. The armies of the Warsaw Pact nations (and the Soviet army in particular) pose a formidable threat to Western Europe where arrayed against these forces are those of the NATO nations. Additionally, Soviet army units can be employed almost anywhere along a seven thousand mile border that extends across the Asian Continent. They are also used, when necessary, to preserve Soviet hegemony over her satellites.

Lacking in warm water ports, reasonably endowed with important natural resources and relying for the most part on internal, overland routes of supply and distribution, the Soviet Union has accommodated, over many years, to the role of a third rate naval power with a navy that was used primarily for coastal defense. It is within the past two decades that a change in Soviet strategy has brought about an intensive effort to build a deep-water navy that is second to none. At present, the primary mission of this growing naval force is one of directly challenging the United States and her allies in their quest for control of the seas. So, while the U.S. emphasizes sea control as a major naval mission, the Soviet navy has as its objective the denial of such control to U.S. forces. It is anticipated that, should the strength of this new Soviet navy continue to increase at recent rates relative to the growth of Western navies, Soviet maritime strategy may well take a new turn. In any sort of developing sea power vacuum, the temptation for the USSR to borrow a page from the book of U.S. sea control strategy might indeed become strong. Were such a development to occur, it would, of course, result in greater symmetry of postures relating to sea control between the two nations.

Over all of the above hangs the ominous cloud of a capability for the United States and the Soviet Union to engage in intercontinental thermonuclear war. While considerations of this capability are well beyond the scope of this paper, it must be noted that the very existence of this threat has certain moderating effects on how missions are fulfilled and operations are conducted at lower levels of conflict.

Conventional Force Configurations -- Land Warfare

How, then, are conventional land and naval forces generally configured to carry out their basic missions, as discussed above, and what are the fundamental factors governing their employment? We will first examine ground/air warfare in this respect, restricting our attention to conflict at the theater level.

The modern armies of NATO and the Warsaw Pact, irrespective of country of origin, are broadly organized along similar lines, though their detailed structures may differ considerably. Such armies are supported by an air arm in carrying out their basic mission. In the case of maritime powers such as the U.S. and U.K. (and, more recently, the Soviet Union), armies are additionally supported by naval amphibious forces to force entry (opposed or unopposed) into enemy territory from the sea. The combined arms nature of this total concept for waging land warfare, while effective, is very complex indeed. It is a concept that had its beginnings back in the mid-nineteenth century, but saw its most rapid development during the two Great Wars of the twentieth century.

To permit accomplishment of the basic missions of land warfare, as discussed earlier, ground/air combat operations concepts have evolved under the particular constraints that the land mass environment imposes on such warfare. These combat operations (excluding those uniquely associated with amphibious support) can be classified as follows:

- Close combat,
- Close interdiction,
- Ground-to-air,
- Close air support,
- Deep interdiction,
- Air-to-air,
- Counter-air strike.

The intricate manner in which the employment of combined arms is woven into the fabric of ground warfare can be appreciated from the fact that the last four of the above operations are basically air operations, all of which impact to a significant degree on the ground fighting. Some operations more directly affect progress of the ground war than do others. For example, effects of air-to-air and counter-air strike operations on the ground war may seem quite remote. Yet these operations adversely

affect an enemy's capability to deliver close air support or to engage in deep interdiction -- to the ultimate advantage of friendly ground force survivability and effectiveness. Thus if one is to model the combat processes of land warfare as a complete, closed system, a two-sided accounting must be made of all operations listed above.

The battlefield and support areas in land warfare generally constitute a large, integral segment of the land mass that, with the air space above, encompasses all of the military activity involved in such warfare, with the possible exception of long intertheater or intercontinental lines of supply and communication. This entire zone of war is traditionally subdivided in depth into smaller zonal areas extending back from the forward-edge-of-the-battle-area (FEBA), the region of contact between opposing ground forces, where maneuver units of up to battalion or brigade size may be engaged. The next larger zone is the division zone contained, in turn, by a yet larger zone, the corps zone or, in large-scale warfare, the Army zone. To the rear of these zones is the communications/logistics zone constituting the rearmost support area. Laterally, or across its width, the battlefield is divided into sectors which typically may each include one or two corps. Each of the operations discussed above can be associated with particular zones or with all areas of the battlefield (as is the case with ground-to-air, air-to-air). Deep interdiction and counter-air strike operations might well extend beyond the communications/logistics zone. In general, combat intensity decreases, whereas support activity increases, as one moves from the FEBA to the rear.

To support the operations being conducted in various regions of the battlefield, the engaged forces are composed of various man-machine combat systems than can be broken down into the following broad categories:

- Infantry,
- Artillery, including mortars and guided weapons,

- Armor,
- Antiarmor,
- Air defense,
- Attack helicopters,
- Tactical air (fixed wing), and
- Tactical nuclear and chemical weapons.

These combat systems, when operationally employed, are supported by the following types of systems:

- Command-control,
- Reconnaissance and surveillance,
- Communications,
- Intelligence,
- Information denial and countermeasures,
- Engineering
- Chemical and radiological defense, and
- Logistic support.

From the foregoing one can create a matrix in three dimensions showing relationships among the categories of operations, combat and support systems and battlefield operations areas or zones. Thinking of the land warfare problem in these terms begins to convey an appreciation (but perhaps barely so) for the complexities involved in modeling the phenomena of land combat. For in addition to the simultaneous, integrated progression during battle of several types of major operations, involving a multitude of differing man-machine systems and the employment of large numbers of weapons, there are the constraining effects of the physical environment to be considered and, even more importantly, behavioral problems associated with the tactics and movement of large numbers of small units, each responding to isolated, decentralized decision-making. There is also a pronounced two-sided aspect to the conduct of land warfare in which decision-making at all levels on both sides is based on perceptions of battle progress or outcome obscured by the "fog"* of war. On the other hand, the <u>continuity</u> and the <u>geographical</u>

containment of land warfare (within a particular area regardless of how large or how small) alleviates modeling difficulty from at least the standpoint that a general combat model structure can be developed quite independently from scenario structure. That this can hardly ever be the case with naval campaigns will be discussed later in this paper.

Land campaigns have generally been prolonged affairs (though future land wars need not be so) whose durations are measured in weeks, or more often months or years. Logistic support, re-supply, reinforcement and manpower replacement are all factors of extreme importance, bearing on the outcome of such campaigns. In theater-level conflict the lines of transportation to the war zone are invariably subject to attack and disruption by enemy forces. Furthermore, in addition to the maneuvering and the physical destruction of men and equipment there is an unending struggle to obtain accurate information on the progress of battle, enemy plans and intentions; and to deny, in turn, the gathering of such information by the enemy. It is this type of information that fuels the command-control processes for both sides in battle by providing input to decision-making at all levels of command. There is an ongoing contest in decision-making (command) and the consummatory ability to exercise control over combat resources. Lastly, there are the sometimes subtle, protracted attempts to inculcate feelings of fear or hopelessness in the minds of an enemy with the intent to destroy civilian and military morale and the will to fight. Thus, we might characterize the totality of land warfare conducted on any large scale as consisting of five rather distinct but interrelated component contests that proceed in parallel once the initiation of armed conflict occurs. These can be described as follows:

- Combat force engagement activity,
- Logistics
- Information warfare,
- Command decisions and resource control, and
- Psychological warfare.

One can readily appreciate that there are countless modeling challenges of inordinate difficulty in attempts to represent land warfare in a manner that accounts for all of the operational factors briefly discussed in this section. A great deal of attention has been devoted to engagement modeling and some to logistics, whereas the modeling of other factors shown is still more or less at the forefront of the art. The modeling of psychological warfare cannot be performed in the abstract and is not known to have been undertaken.

Conventional Force Configurations -- Naval Warfare

In next addressing the subject of the naval warfare operations environment, an attempt will be made to parallel the treatment accorded the land operations environment, presented above. It, again, should be noted that the scope of our investigation is limited to the naval mission of sea control.

Starting from the premise of fundamental mission similarity for both land and naval warfare -- the attainment of area control -- it is the vastly differing geophysical environment for each that is responsible for pronounced differences to be found in their respective operations environments. How do we describe these differences and how can we deal with them? In the following discussion, certain inferences will be drawn from the modeling world to be applied to the world of operations.

In shifting attention to naval warfare, we part company with the concept of the battlefield which, in the land warfare environment, proves to be a valuable integrating and bounding mechanism. There is no such thing, however, as the equivalent of a circumscribed battlefield in naval warfare. This fact introduces some distinct differences in the way naval operations are defined and in the modeling of sea control combat.

In land warfare, it is generally possible to structure a model of the process with relatively little reference to any particular scenario. There is a certain symmetry to the activities

on both sides and a degree of predictability as to how the battle will be fought. The selection and definition of a scenario serves to establish the boundary conditions and to provide input information for specific application of the combat model.

In naval warfare, where vast, featureless ocean areas are potential arenas for naval encounters and engagements, there can be distinct asymmetries in the forces of attacker and defender and the nature of battle evolution is quite unpredictable. Therefore, the structure of a naval combat model must, of necessity, be more dependent on the scenario. Under these circumstances the scenario establishes the parameters and dimensions of the threat, based on relevant time and space considerations and determines where engagements will occur. There appears to be implicit recognition of these facts in the manner in which naval tactical operations are defined. These operations are compartmentalized into distinct "warfare" areas, such as antisurface warfare, anti-air warfare, antisubmarine warfare, etc. From this point of view, it is as if a total naval capability can be assembled as needed from a collection of separate, relatively independent operational capabilties and embodied in a naval force to meet offensive and defensive requirements for a specific mission.

Also to be noted in the "warfare" concept of operations is compartmentalization of the threat as to the medium in which it operates (air, surface, underseas). This seems to reflect a discounting of the likelihood of enemy attack in more than one medium at a time. Whether or not such attacks can be mounted, the types and numbers of weapons that an enemy may bring to bear and the degree to which the attacks can be sustained are all determined in large measure by scenario dependent factors. These factors, in broad terms, relate to geography, geopolitical considerations, orders of battle, positioning of friendly and enemy units, fleet transit distances, etc. This is in rather sharp contrast to the modeling of land combat where, once the battle is

joined in accordance with scenario dicta, many operations proceed simultaneously in a multi-threat environment controlled by model logic or by human players interacting with the model. Combat activity in land warfare, once initiated, tends to flow in relatively continuous fashion for protracted periods. In naval warfare, combat activity is generally discontinuous, with forces only sporadically in contact for brief periods of time.

Delving into the subject of naval operation in somewhat greater detail, we find that the broad mission of sea control has component missions of:

- Area sanitization (or denial of access),
- Sea line of communication (SLOC) protection.

The first component mission is concerned with clearing a designated maritime area of air and naval threats to friendly forces and maintaining the area in a threat-free state so that further naval operations can be conducted within or from the area. The second component mission is one of providing, in the limit, <u>local</u> protection for shipping moving along specific sea lanes. In a general sense, SLOC protection can be considered a special case falling under the umbrella of area sanitization. However, in practice, SLOC protection is more usually limited to the concept of defending moving points on the ocean's surface rather than maintaining threat neutralization over a fixed area.

There are basically three types of operations that can be employed to accomplish the two missions identified above. These are:

- Barrier operations,
- Offensive action (air, surface, and submarine campaigns),
- Active and passive defense.

The first two types of operations are most directly associated with the mission of area sanitization, with recourse to defensive postures as necessary. All three of the above are

important to SLOC protection, though heaviest emphasis for this mission probably falls on the ability to conduct effective operations in active and passive defense. In addition to the three types of combat operations listed, there is a force transit operation from force marshalling points to an operating area. Force transit may be opposed or unopposed. In the event of the former, the force would resort to defensive measures.

The three types of operations for sea control can be further broken down into the following "warfare" operations areas, discussed earlier, that are traditionally used to describe the major components of naval tactical warfare in its entirety.

- Air, anti-air,
- Submarine, antisubmarine,
- Surface, antisurface,
- Mine, anti-mine*.

In the above listing, each type operation occurs in both an offensive and an associated counter-offensive mode. However, as with the oft-quoted observation that "offense is the best defense," the line of demarcation between what exactly represents offensive or defensive action, is in certain instances, quite fuzzy. Anti-air warfare, for example, includes an action component calling for the destruction of enemy aircraft on their airfields. This type of activity could also be an element of strike warfare, an offensive operation associated with the mission of power projection.

It is difficult to correlate naval operations, using the partitioning described above, to those that pertain to ground/air

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* In addition to the warfare (or operations) areas listed are strike warfare and amphibious warfare, both related to the naval mission of power projection rather than sea control. Power projection, in turn, impacts directly on the conduct of land warfare, as noted earlier, but is not the naval mission topic of discussion of this paper.

warfare operations, as discussed earlier. It is a fact that the operations in both instances are vastly different due mainly to the differences in physical and geo-political environments. Not too surprising, however, are some striking similarities that exist and some parallels that can be drawn. Barrier operations, can, for example, be likened in a broad way to fortified line concepts, such as the Maginot Line, in ground combat. Offensive action for area sanitization is fundamentally similar to the "search and destroy" ground operations employed in Viet Nam and even more directly, perhaps, represents an expansion of "hunter/killer" techniques employed in antisubmarine operations. Mining and mine sweeping operations, except for scale, are fundamentally similar concepts on land and on the sea. Both land and naval warfare are concerned with surface-to-air defense, with air-to-air combat and with air-to-surface action even though the roles played by such operations relative to other combat activities in the two warfare domains may differ considerably.

The classifications of operations in land and naval warfare, as presented above, appear to derive from disparate points of view; the former reflecting that of a combat commander, the latter that of a type commander. Whether such indeed are the origins of the classification format in each case, or whether one can do little else in naval warfare because of the unpredictability of sea combat structure, is difficult to say. Aside from observing the existence of operations similarities between the two forms of warfare, one is left with an exercise in "comparing apples to oranges".

The numerous combat systems employed to carry out the sea control mission in naval warfare can be identified in highly summary fashion as follows:

- Combatant ship
  - Platforms, sensors, weapon systems, (anti-air, antiship, antisubmarine)
- Combat aircraft, (shipborne)

- Platforms, sensors, weapon systems (anti-air, air-to-surface, antisubmarine)

- Maritime patrol aircraft (land-based)
  - Platforms, sensors, weapon systems (antisubmarine, air-to-surface)

- Submarine
  - Platforms, sensors, weapon systems (antiship, antisubmarine)

These systems are described in greater detail in the left hand column of Table II. The combat systems, in turn, are supported by the following types of systems:

- Reconnaissance and surveillance,
- Command and control,
- Communications,
- Communication and operations security,
- Intelligence,
- Concealment, deception and information denial,
- Radiological and chemical defense,
- Logistic support.

These systems, designated by the Navy as Command Support Systems, are presented in greater detail in the right hand column of Table II. They are roughly equivalent to the combination of what are classifed as combat support and combat service support systems in land warfare.

Of paramount significance to modeling is the plethora of complex systems that are involved in naval warfare, as noted in Table II, and the multi-functional characteristics of naval ships and aircraft. Much of the dependence on technologically sophisticated sensors and weaponry stems from the greater variety of intra- and intermedia operations (see Table I) called for in sea control combat where sensing, tracking, homing and warhead fuzing in the atmosphere and under water make use of magnetic field, electromagnetic wave (visible light, infrared and microwaves) and acoustic phenomena. By contrast, land warfare systems tend to be

Table II
Naval Warfare (Sea Control) Systems

Combat Systems

- Combatant Ship Systems
  - Platforms (carriers, cruisers, destroyers, frigates, etc.)
  - Guns (anti-air, antiship)
  - Missiles (anti-air, antiship, antisubmarine)
  - Sensors (radar, sonar)
  - Aircraft (CTOL, V/STOL)
  - Helicopters (ASW)
  - Homing torpedoes, depth charges
  - Mines, mine sweeping
- Combat Aircraft Systems (Shipborne)
  - Platforms (fixed wing-fighter, attack ASW, AEW; helicopters-ASW)
  - Missiles (anti-air, antiship, air-to-ground)
  - Guns
  - Sensors (radar, sonobuoys, MAD)
  - Homing torpedoes, depth charges
  - Bombs (guided, unguided)
- Maritime Patrol Aircraft Systems (Land Based)
  - Platforms (fixed wing-ASW, attack)
  - Sensors (radar, ESM, MAD, Sonobuoys)
  - Antisubmarine torpedoes
- Submarine Systems
  - Platforms
  - Sensors (sonar, radar)
  - Missiles (antisubmarine, antiship)
  - Homing Torpedoes

Support Systems

- Reconnaissance and Surveillance Systems
  - Satellite (photo, radar, ELINT)
  - Fixed sound detection arrays (SOSUS)
  - ESM, ELINT (Surface ships, aircraft)
  - Over-the-Horizon radar
  - Airborne Early Warning
- Command and Control Systems
  - World-wide Military Command Control System (WWMCCS)
  - Naval Command Control System (NCCS)
  - Combat Direction Systems (CDS)
- Communications
- Communications and Operations Security
- Intelligence
- Concealment, Deception and Information Denial
  - Electronic warfare (ECM, ECCM, decoys)
  - Acoustic warfare (noisemakers, decoys)
  - Tactical Cover and Deception
- Radiological and Chemical Defense
- Logistic Support
  - Shore Establishment Support
  - Forward Basing Support
  - Overhaul and Repair
  - Replenishment
  - Manpower
  - Transportation

Abbreviations:
AEW - Airborne Early Warning
ASW - Antisubmarine Warfare
MAD - Magnetic Anomaly Detection
ESM - Electronic Surveillance Measures
CTOL - Conventional Take-off and Land
V/STOL - Vertical/Short Take-off and Land
ELINT - Electronic Intelligence
ECM - Electronic Countermeasures
ECCM - Electronic Counter-countermeasures

more single-purpose in design and technically less complex, since they lack the extent of environmental control, sources of power and facilities for test, maintenance and repair generally to be found aboard naval ships and submarines.

Relatively short range artillery and automatic weapons delivering large numbers of rounds account for the bulk of ground combat firepower. The situation is quite different in naval warfare where the major weapons are large, complex missiles. Naval weapons' size, complexity, cost, and limitations in vehicle magazine capacity (with little opportunity for weapon replenishment during battle) all tend to restrict the numbers of these weapons that can be employed in a typical naval engagement.

Without the need to occupy an area in order to control it in naval warfare, the concept has evolved for the employment of mobile carrier battle groups and surface action groups as a cost effective means of establishing a strong naval presence in large ocean areas. These groups are generally small, consisting of from five to twelve combatant ships, but they represent an enormous capital investment. It is quite possible that a relatively small number of extremely costly vehicles, defending themselves with a limited number of complex weapons, could under certain circumstances, be subjected to overwhelming enemy attack -- particularly, multi-media attacks delivered in coordinated fashion, as mentioned earlier. Most certainly, enemy incentives for such coordinated action are present and all that is required is the proper set of circumstances. The very possibility of such an occurrence places much heavier emphasis on passive defense measures in naval warfare than is likely to be encountered in ground combat. These measures involve the rather extensive use of electronic and acoustic warfare techniques and, whenever possible, a reliance on surprise and the exercise of tactical cover and deception. While this is not to minimize the importance of the use of terrain in land warfare for concealment in the achievement of surprise, or the use of passive countermeasures

against communications in land warfare, naval combat does call for more clearly equal employment of active and passive defense measures.

The "Granularity" of Land and Naval Warfare

Perhaps one of the most important factors that, in combination with many of the above considerations, introduces significant differences in the structure of land and naval warfare models is that of the "granularity" of the two forms of combat. In modeling parlance, "granularity" is related to "resolution" which, in turn, is related to "aggregation." For the purposes of further discussion we will observe that:

> Small (large) granularity = high (low) resolution = low (high) level of aggregation.

If we now consider the smallest unit in a combat situation that enjoys virtual independence in its ability to "shoot, move, communicate" and identify this as the "unit of resolution" for purposes of modeling the action, we find this unit of resolution should properly be the squad, or perhaps even the individual soldier in land combat, whereas in naval warfare, it can be an entire ship, submarine or aircraft. In the naval case, up to many hundreds of crew members are all constrained to move as one within the hull of their ship and what the ship does in transit or in combat reflects the decisions of her commanding officer and the integrated teamwork of the entire crew functioning as a unit. Thus, land combat is a small granularity phenomenon whereas naval combat tends to of much larger granularity. This fact has continually posed a serious dilemma for land combat model developers for it is virtually smpossible to account for the field activities of each individual combat soldier or squad in the modeling domain. To circumvent this difficulty, land combat models of the highest resolution make use of notional squads, platoons or companies that are composed of individual soldiers all exhibiting

identical behavioral characteristics. This, of course, is a departure from reality in that the members of such combat organization are not physically constrained to operate as a unit, as is the case in naval warfare. With this artifice and with the further aggregation of units, the granularity of land combat models is usually raised to a higher level than exists in actual combat.

We observe, then, in contrasting the two forms of warfare that naval combat consists of a relatively small number of highly discrete high-value units, equipped with complex sensing systems, that must mainly rely on a limited number of highly destructive weapons in order to conduct offensive and defensive operations. Land combat, on the other hand, involves a much larger number of lower value units, each with less destructive power. Furthermore, naval combat calls for heavier emphasis on concealment, deception and information denial techniques as an adjunct to active defense measures. Naval combat also tends to be composed of a series of one-on-one, one-on-several and several-on-several engagements each of which is important to final battle outcome while land combat consists of a multiplicity of many-on-many engagements that are customarily treated by models in aggregated fashion in order to reduce model complexity. These factors work in favor of high resolution modeling of naval systems, during engagement, to account for the expenditure of scarce but highly lethal munitions, and for the pronounced effects on engagement outcomes of the use of countermeasures, counter-countermeasures and other "soft-kill" techniques by both sides. Paradoxically, naval combat modeling can accept large granularity in representing the behavioral aspects of warfare while calling for small granularity in modeling its technical aspects. This, in fact, is a basic characteristic of naval warfare. When compared with land combat, naval actions tend to be more clearly dominated by technical aspects of systems that use highly automated combat procedures.

A comparison of logistic trains in the two forms of warfare reveals some interesting differences. In theater-level land combat, especially for U.S. forces, the pipeline for the flow of manpower, equipment, provisions, and munitions is normally lengthy (often intercontinental), critical and vulnerable to enemy attack. Since land combat tends to be a continuous, protracted affair, the necessary logistical flow takes on characteristics of a continuous process. The magnitude of logistic support to land warfare is such that the SLOC protection component of sea control becomes one element of the intertheater logistic operations supporting a theater-level land conflict. Any complete view of the theater-level problem properly includes the impact of sea control and naval power projection missions.

In contrast the logistic support of naval forces, like most other aspects of naval warfare, is a highly discrete process. There are basically four sources for the replenishment of surface forces:

- Fast combat support ship with battle group,
- Underway replenishment group,
- Advanced bases,
- Home ports.

The critical items of supply are ammunition, fuel, and provisions. For underway replenishment, the first means shown above (an AOE or AOR behind the battle group defensive screen) has been gaining favor over the second, which consists of a separate formation of logistics ships with escorts that can rendezvous with a battle group at sea. Maritime patrol aircraft operate out of home or forward bases, depending on circumstances and geography, as do submarines. The first two concepts are relatively vulnerable to enemy action and enemy attrition of logistic support has a more immediate and direct effect on combat capabilities than in land warfare. Also worth noting is the fact that there can be little reinforcement or replenishment of forces during a naval surface engagement and there are seldom opportunities to dis-

engage and withdraw once the battle is joined. Actual combat, as already noted, occurs sporadically, the action is intense, and of short duration. Clearly, much of the mission time for combat units is spent in transit between bases and operating areas.

To summarize the discussion so far on operating differences in land and sea control warfare, it is illuminating to compare them with respect to the major components of conflict identified for land warfare (page 30). These, it appears, are also applicable to naval combat, recognizing, however, that psychological warfare is not a significant factor in a sea campaign.

Combat Force Engagement Activity

"Combat force engagment activity" has been discussed at considerable length and can be summarized as follows. Compared to naval combat, land engagements inherently encompass more variables and are more complex. In addition, land combat tends to be an amorphous combination of large numbers of small units and weapons, while naval combat involves fewer discrete units, each of which has a relatively high unit value. A generally higher level of application of technology is feasible on naval vessels in comparison with most land force weapon systems. One consequence is greater relative importance of technical equipment in naval combat, and hence a high value for individual hardware components such as the search radar on a carrier or cruiser. Sea control combat models can afford to place emphasis on quantitative simulation of technical equipment characteristics and performance, whereas the modeling of land combat engagements faces the more difficult problem of simulating interrelationships among a great many factors that are difficult and often impossible to quantify, given the existing state of knowledge.

Logistics Warfare

In "logistics warfare" there is a large difference in scale between land and naval warfare. Much of sea control as a naval mission is encompassed within the logistic loop of theater-level

war. Hence logistic support to naval units is a "wheel within a wheel," discontinuous in nature but highly critical to the success of the naval mission as it is to theater logistic support. It is of little consequence during actual naval combat since reinforcement and resupply are heavily limited under combat conditions. Nevertheless, the vulnerability of logistics units to enemy attack, particularly those involving ships that move or must rendezvous with a battle group, should properly be evaluated in models of sea control.

Logistics in land warfare at the theater-level is exceedingly more complex. Since this form of combat is usually a phenomenon of protracted duration, it involves an almost continuous flow of supply by sea and air into and within the theater. Disruption of this flow (depending on degree of severity) will generally not have the more immediate effects on combat operations that might be expected in naval warfare. However, there are serious difficulties to be faced in determining the time dependent magnitude of these effects on land force combat effectiveness.

Information Warfare

The role of information warfare in naval combat is magnified considerably by the irrefutable importance of surveillance in maritime operations and the extensive use to be made of electronic and acoustic countermeasures to offset enemy saturation of the "hard-kill" systems in a force. The use of cover and deception techniques is also included in information warfare and is called for when there is a desire to minimize the probability of own force detection and encounter with the enemy or to achieve an element of surprise. While all of these factors are also important in land warfare they tend to be overshadowed by the emphasis on raw firepower that is a characteristic of ground/air operations. Modeling the consequences of information warfare is however, a very difficult undertaking that calls for a two-sided evaluation of command decision processes when deception, countermeasures or counter-countermeasures are employed.

Command Decisions and Resource Control

"Command decisions and resource control" essentially covers the decisions that are made and the control over force activity that is exercised, all based on the information made available to the command structure at various levels. This information generally covers the status and capabilities of friendly and enemy forces, action reports, and evolving indications of enemy intentions. For both land and sea warfare, the command structure starts with the National Commands Authority (NCA) at the very top. Next, the structure includes the theater supreme commander. Branching to the naval side and moving down the command ladder, we find the area fleet commander-in-chief, the numbered fleet commanders, the type commanders for submarines and marine patrol aviation, the carrier battle group/surface action group officers in tactical command and, finally, the commanding officers of individual ships, submarines and aircraft squadrons. On the ground force side are the Army group commanders, Army commanders, and corps commanders, followed by division brigade, battalion, company, platoon and squad commanders. These Army echelons are matched by comparable ones in theater air forces.

In the abstract, it is not possible to draw comparative inferences concerning the two branches of command structure outlined above or the nature of decisions that are made at the various levels. What is clear is the distinct challenge presented to model developers to represent adequately the command and control processes in models of both land and naval combat. The preferred method at the present time for treating command and control is to have human players interact with battle simulations. These players make "command" decisions based on battle progress, these are entered into the computer and the game proceeds accordingly. At the lower levels of tactical command and control, naval systems tend to be routinized and automated in their response to enemy actions, more so than are most ground combat systems. This simplifies the task of command and control representation at

weapon system levels in modeling naval combat. ASW engagements, and, as noted above, the use of deception techniques and countermeasures are most difficult to model from the standpoint of representing opponent's reactions to the uncertainty and confusion that are likely to prevail under such circumstances.

US/USSR; Symmetry/Asymmetry

As an adjunct to the discussion of differences in modeling land and sea control warfare, there are some important observations to be made concerning asymmetries in both posture and operations of Soviet/Warsaw Pact forces and those of the U.S. and NATO. In land warfare, drawing on a European Central Region scenario, as an example, we find a general complimentarity of objectives for the opposing sides, with the Warsaw Pact forces assumed to attack initally and NATO forces to defend. There is also a general symmetry of force organization on both sides, each having mechanized infantry, armor, air support, air defense, etc., organized in similar units. In the matter of tactical concepts, however, there are some sharp differences. Notable among these are the strong Soviet emphasis on armor for conducting a war of movement; their preoccupation with the concept of continuous combat operations of high intensity, both day and night, for protracted periods; their more ready willingness to use whatever weaponry it takes to carry out the mission (including tactical nuclear and chemical munitions); and their heavy reliance on many layered air defense systems. Doctrinal factors such as these must be reflected in models of land combat.

In the area of naval warfare, sharper differences in strategies and operations are to be found. For the present, at least, the Soviet idea of naval war is quite different from that of the U.S. The U.S. strategy is to control the seas for the many reasons already stated. The Soviet strategy is simply to deny the U.S. this capability for sea control, in true "spoiler" fashion. Therein lies a significant asymmetry in objectives that is reflected in the types of ships, aircraft, and weapon systems

the two superpowers are producing for their naval forces and the tactics they plan to use. Apart from the implications of sea control for the economies of Free World nations in peacetime and war, and the role of SLOC protection in time of war, it is also essential that the U.S. Navy be able to fulfill the mission of ocean sanitization in order to permit the projection of naval power ashore in support of land operations. Under such circumstances, the U.S. cannot afford to expend its entire fleet in the quest for sea control. It must maintain a healthy residual to carry out subsequent missions made possible by the attainment of control of the seas. Such is not the case for the USSR. If necessary, it could well choose to sacrifice the bulk of its navy if doing so would block the U.S. from achieving mastery of the seas.

The fleets of the two superpowers do indeed reflect these notions. The Soviet fleet, like her army, is built around the concept of a hard first strike and a short, victorious war; yet capability is retained to fight a long war if necessary. Damage control and ship survivability are generally inferior in Soviet combatants, ammunition and heavy missile replenishment at sea cannot be performed, and Soviet crews are not expected to repair many of their shipboard systems while underway. Attributable in part to its origins as a coastal defense force is the heavy Soviet Navy emphasis on the use of submarines by the Soviet fleet, where these vehicles are assigned a greater number of missions in tactical warfare than are their U.S. counterparts. Perhaps of greatest concern to friendly forces is the anti-shipping mission directed against merchant and naval ships (particularly aircraft carriers) in which cruise missiles and torpedoes are employed. Soviet tactical submarines, many of them nuclear powered, outnumber those in the U.S. fleet by a ratio of approximately 3.5 to 1.

The evolving Soviet interest in carriers provides, perhaps, a portent of things to come. Starting with the advent of the

U.S. Polaris submarine, the Soviet focus was on helicopter-carriers (Moskva class) and the ASW mission. With a subsequent carrier class (Kiev), V/STOL fighter/attack aircraft were added to a complement of ASW helicopters. Very recently construction was started in a large carrier that can launch CTOL high performance aircraft. This approaches symmetry with the U.S. fleet posture relative to carrier employment and raises the possibility of a future Soviet fleet mission in the area of power projection. For many years, however, the Soviets have relied on land-based aviation for long range strike, reconnaissance, coordination, and command control in support of naval operations. These aircraft, for the most part, are standard Soviet Air Force bombers modified for naval missions. In addition the Soviets have produced in large numbers special purpose, long range ASW aircraft (land-based) to supplement what are already impressive ASW capabilities afloat.

In addition to the trends noted above, the Soviets are building a large surface fleet of light and heavy cruisers and numbers of smaller escorts such as destroyers and frigates (which presently outnumber those in the U.S. by a ratio of about 2 to 1). Dual ASW and anti-ship capability is being stressed (with no neglect of anti-air) and the many differing types of anti-ship missiles under development, compared to the U.S. and her allies, is indicative of Soviet dedication to the anti-ship mission.

Thus, we find that there are some rather distinct asymmetries in U.S./USSR postures and capabilities when it comes to naval warfare, certainly more pronounced than in the case of land warfare. In addition, naval engagements are, more often than not, likely to be asymmetrical with respect to the types of vehicles and systems employed by attacker and defender.

Return to Principles

The many differences in physical and operational environments discussed in this and the preceding section will lead to

models of naval combat on the one hand and land combat on the other that are obviously dissimilar in specific content. It is not surprising, of course, to find, for similar combat processes, subroutines and algorithms in both types of models that appear to bear no resemblance to each other, since radically dissimilar environments are being depicted. A most important point, however, in both sea control and land combat modeling is that attention to portraying obvious details of the operational environment not be so demanding that little thought is given to adequate portrayal of the principles that universally guide combat and combat commanders both in land and naval warfare. Unless models are designed with fundamental combat missions and principles at the forefront, their results stand in danger of being deceptive and the interpretation of these results will be lacking in breadth. It is a major premise of this paper that avoidance of these difficulties is best served by having model designs proceed from a top-down perspective. This is a premise that seems to be gaining increased acceptance within the land combat modeling community and one would hope that it would be as fully appreciated among modelers of naval warfare and users of naval models.

IMPLICATIONS OF NUCLEAR AND CHEMICAL WARFARE

This section will address the implications for modeling of the use of "unconventional" weapons in land and naval warfare, as an extension of the operations environment discussion in the preceding section. This organization of presentation should not be construed as reflecting a view that unconventional weapons employment is merely an additional firepower layer over the more traditional modes of land and sea combat operations. In reality, the use of these weapons would profoundly affect operations, though not to an extent that exceeds the bounds of any of the principles of war. Provisions for transitioning from a conventional to an unconventional warfare mode must be well established before the fact.

Nuclear and chemical warfare present special requirements for combat modeling because of the massive destructive power of the weapons and the absence of combat experience in their use. In examining contrasts between sea control and land combat, it is useful to consider the impact of these extreme modes of warfare upon the employment of general purpose forces in the two forms of combat.

The differences in impact are appreciable. The differentials in kind are not distinct from those that have been cited above under the discussion of missions, geophysical environment and operations environment; but the potential for sudden, widespread devastation from nuclear and chemical weapons magnifies already cited differentials between naval and land combat. For both forms of combat, the enormous impact that such weapons can have dictates that their use be treated and tested in models. In the case of land combat, the nuclear/chemical modeling problem is much more complex than for sea control combat.

Probably the most significant impact differential arises because land warfare is conducted in areas usually inhabited by humans, the control of whom, together with the lands and

developed resources, is the basic object of land warfare. The employment of mass destruction weapons poses great difficulties in discriminating between damage to noncombatant people and economic resources and damage to military targets (the collateral damage problem). The possible intentional use of such weapons against large segments of the population and industry, or use against military targets in a manner that disregards collateral civil damage raises further issues that must be addressed within the scope of land combat modeling. In addition, given the universally widespread fear of nuclear and chemical weapons, there is the possibility of massive psychological reprecussions among both combatants and noncombatants to be considered. The enormous stakes so suddenly at risk heightens uncertainty and minimizes response time, thus fueling pressures to escalate nuclear/chemical weapon employment or to initiate their use at a high level from the outset. These political and psychological complications of land warfare are greatly diminished in the case of sea control combat, for sovereignty, control of people and rsources, and catastrophic losses of civilian lives and property are not directly threatened.

These political-psychological combat differentials are augmented by differences in the combat operations environment itself. While military losses from nuclear/chemical weapons can be dramatically rapid in both land and naval warfare, the magnitudes of losses of personnel and equipment are likely to be more extensive in land combat. In addition, the possibilities of widespread nuclear and chemical contamination, of massive impediments to movement, and of compounding system breakdowns in the land combat environment can create major, protracted, and unpredictable changes in the course of events. In comparison, modeling nuclear/chemical damage and contamination problems in sea control combat remains, as in conventional warfare, largely a discrete ship-by-ship analytical problem. A matter of further concern is that of possible asymmetries in U.S. and USSR

inclinations and readiness to use unconventional munitions, the provisions made in their respective command structures to authorize the release of such weapons, and the doctrines that govern their employment. This, of course, applies to both land and naval warfare environments where environmental differences can superimpose further effects on adversary attitudes and practices relating to the use of such weapons.

In summary, there are significant differences in the impact of nuclear and chemical weapons upon naval and land combat. The differences stem from and mirror differences in the missions of land and sea control forces and in their respective combat environments. They encompass potentially dominating political-psychological factors at play in land combat and pervasive effects on land forces and the land combat environments, matters that are likely to be less critical in naval warfare. It is this very fact that may favor less inhibited use of these unconventional weapons in a naval combat environment. Not withstanding these significant differentials in the manner in which nuclear/chemical combat might progress, the possibility of dramatic alterations in the course of sea control combat dictates that nuclear/chemical modes of combat continue to be addressed as important elements of the total sea control modeling problem.

MODELS AND COMBAT THEORY: A UNIFIED APPROACH TO MODELING LAND AND NAVAL WARFARE

The earlier sections of this paper have been devoted to a broad discussion of mission, environment and operations pertinent to tactical warfare conducted on land and on the sea. We now focus our attention on the subject of how these combat phenomena can be modeled, stressing the issue of model structure and design rather than the development of any explicit form of model construct. Most importantly, we will attempt to ascertain if there are unifying principles that can be identified in combat modeling architecture that hold despite wide variations in the combat phenomena being modeled. In short, then, the question is whether one can define a single construct that is equally applicable to the modeling of both forms of combat (and, possibly by extension, to <u>any</u> form of combat).

The definition of such a structure can be looked upon as a significant element of combat theory -- or, at the very least, a way to think about combat problems in a consistent analytical fashion. Even assuming that we are able to identify the important pieces of the problem and their relationships in some logical, internally consistent fashion, we must recognize that our ability to <u>quantify</u> all of these in a proper manner may have to await later availability of data and advancements in modeling technique. The connection between ideas expressed in the exposition that follows, and the much broader subject of combat theory is based on the major, but simple, premise that a theory, in the final analysis, is a verifiable <u>model</u>. Should this hypothesis prove overly simplistic, the subject under discussion becomes one that addresses a "theory of modeling." Regardless of how we choose to describe the endeavor, its findings are believed to be useful and informative in clarifying fundamental relationships among the factors that influence combat outcome.

In the most general analytical terms, the modeling of combat is concerned with the mathematical representation of military activities in time and space. There are boundary conditions imposed on these activities regarding conflict initiation, objectives, order of battle, force structure, force characteristics, tactical operating procedures and doctrine, the criteria controlling conflict termination, and other factors. Some of these conditions may initially be described in qualitative terms, but the aim at all times must be to maximize the translation of these conditions into the language of mathematics (implicitly or explicitly) in order that modeling of the phenomena continue to constitute a justifiable endeavor. Furthermore, the involvement of a 'time' dimension dictates that some dynamic representation of combat activity be formulated and the 'space' dimension implies that a mapping or plot of all units engaged in the conflict can be developed and maintained as a function of time for the duration of the conflict.

Expanding on this simple notion of combat modeling, it is important that we next define some terms.* There is a significant hierarchy of key terms around which much of our structural concept for models of combat is formulated. This hierarchy consists of the following:

- Objectives
- Missions
- Operations
- Processes
- Functions
- Action events

In brief, one has an objective (or goal). The translation of this objective into a task constitutes a mission. Undertaking

*/ It is recognized that the subject being addressed is fraught with semantic difficulty but by the stating of our intended useage of certain key words, we can at least reduce the dangers.

the mission involves the conduct of specific operations. Operations, in turn, are composed of and can be analytically addressed and assessed by component combat processes. Each combat process can be broken down into certain functions, the performance of which effectuates the process. These functions can be further broken down into series of action events. In this hierarchy, the term, 'processes' has an especially important analytical connotation in addition to its use in identifying major types of military activity, such as attrition, suppression, movement, etc., that impact on final battle outcome. Processes, as well as the other terms shown, will be addressed in greater detail later in the paper.

Returning to the subject of combat modeling as the representation of activity in time and space, we will first address the dynamic or temporal aspects of the problem. A generalized concept of the dynamics of combat is shown in Figure 1. This concept is empirically derived from the study of several dozen combat models of ground/air warfare performed in Reference 1. The figure depicts an idealized structure that, while implicit in most of the models studied, is never entirely satisfied by any one model. The development of such a construct resulted from the attempt in Reference 1 to evaluate the relative merits and the completeness of different combat models in simulating the actual conduct of ground warfare.

Figure 1 illustrates, in the lower left hand corner, friendly combat and logistic forces which are composed of manpower and systems that exhibit inherent performance characteristics and capabilities which are measurable in an engineering, laboratory or proving ground sense. These capabilities are subject to control by the commander, who can mold them, in the combat environment, into an appropriate level of combat power to be directed effectively against the enemy. Out of the interaction between friendly and enemy forces there emerges a continuing measure of friendly force effectiveness with respect

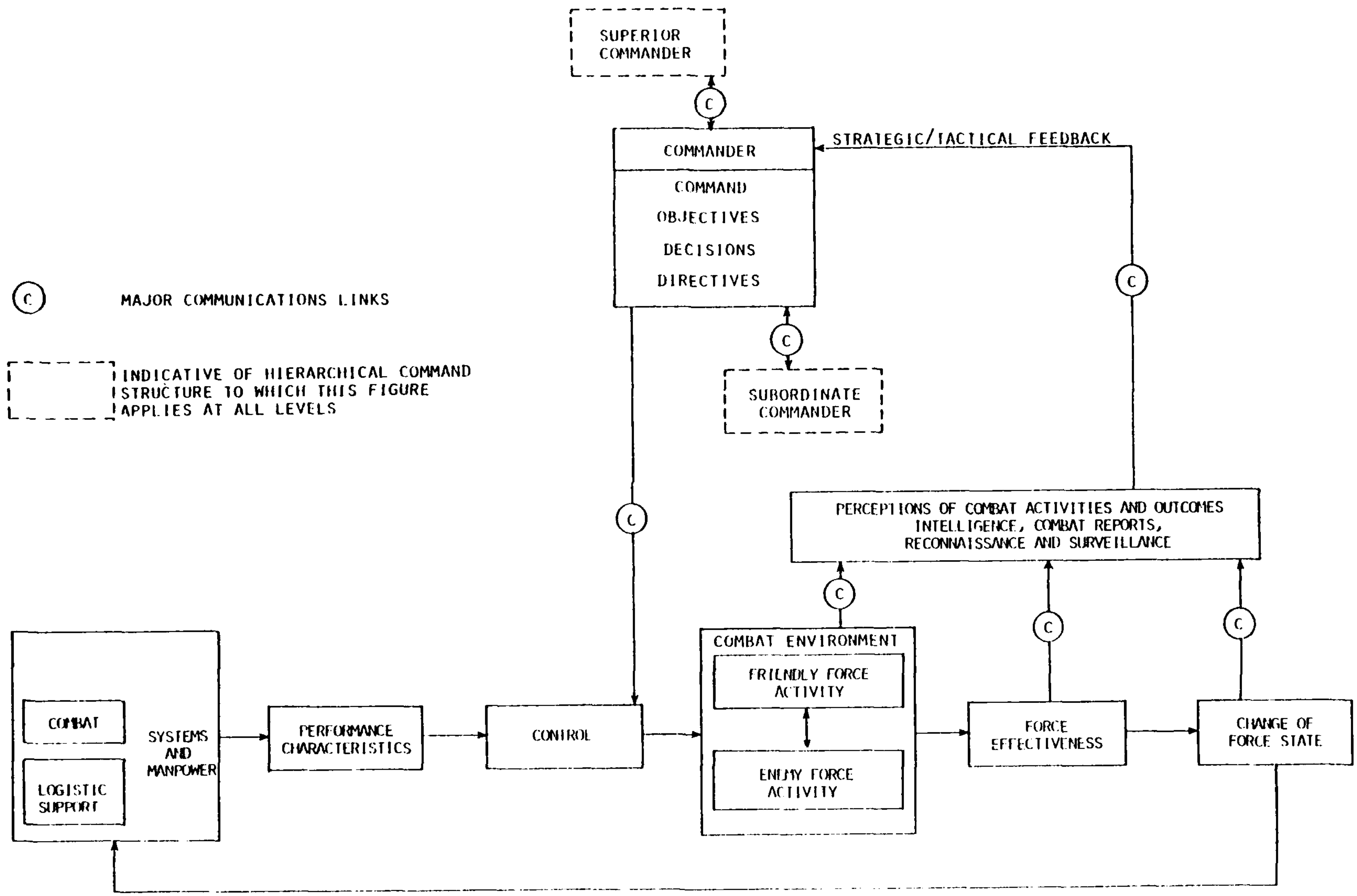


FIGURE 1 CONCEPT OF COMBAT DYNAMICS

to progress toward the objectives selected by the commander. This force effectiveness is coupled to changes in force state that also result from the combat interactions of friendly and enemy forces.

Of utmost importance is the "Perceptions" block in Figure 1. Into this block feeds information on the two-sided combat activity, friendly and enemy force effectiveness, and changes in force state on both sides. Within the block the information on friendly forces and intelligence on enemy forces, incomplete and partly erroneous as both maybe, are formed into perceptions of the reality of combat action, a crucial distinction from actual reality. Thus, the 'perceptions' block represents the processing of available, but faulty and partial information into a perceived reality that differs from actuality in greater or lesser degree. It is the perceptions of what is occurring that are formed by the staff and the commander that serve as the bases for decisions to perhaps modify objectives or to vary the tasking of forces. Associated with the "commander" block are superior and subordinate levels of command, reflecting the hierarchial structure of command. The figure in its entirety can be as well applied to any higher and lower command level.

Implied in Figure 1 is the fact that logistic forces are also involved in an extended combat environment. These forces provide the combat forces with manpower, food, fuel, ammunition, replacement equipment, repair facilities and spares. Such forces and the logistic pipeline they define are subject to enemy attrition and disruption. The same is true of the communications network shown in the figure and the information gathering systems that support tactical and strategic intelligence processes.

Two major contiguous loops can be identified in Figure 1. The first is a "combat activities loop" which appears across the lower part of the figure and the second is a "perceptions/command-control" loop that draws from and operates on the "combat

activities" loop. A third loop (both action-oriented and geographical) implicit in Figure 1, but not shown as such, is that of logistics support. The logistics support loop functions for the most part outside of the immediate battle environment but falls under the operational purview of battle command and control. It is subject to enemy interdiction thus laying claim to a combat environment of its own.

Figure 1 illustrates combat dynamics from the point of view of only one side. An identical figure can be constructed for the enemy forces. To properly represent the conflict, we must integrate two symmetrical dynamic flow diagrams, one for friend and one for foe that interact with one another in the combat environment. Such a construct is shown in Figure 2.

On reflection (and after considerable hypothesis testing), Figure 1 and 2 suggest that the dynamics portrayed have universal application to all levels and all types of warfare.* But the concept, as it stands up to this point in the discussion, is merely a qualitative one. To introduce the quantitative aspects of combat modeling, one must factor into the dynamic structure shown in both figures a set of interdependent routines or algorithms that represent explicit combat processes. These processes are responsive to command objectives and missions (see page 51), and occur at appropriate points of the dynamic structure. The processes consist of force destruction/attrition, force neutralization/suppression, movement and maneuver; and command and control, communications, intelligence, deception and logistic support. These processes in a modeling sense are mathematical functions that transform various inputs (independent variables) and components of other processes into local process outcomes (dependent variables) that, in turn, drive the overall outcome of the conflict, defined by adversary objectives.

*It can in fact be shown that the dynamics of Figures 1 and 2 can be further generalized to apply to virtually any adversary situation.

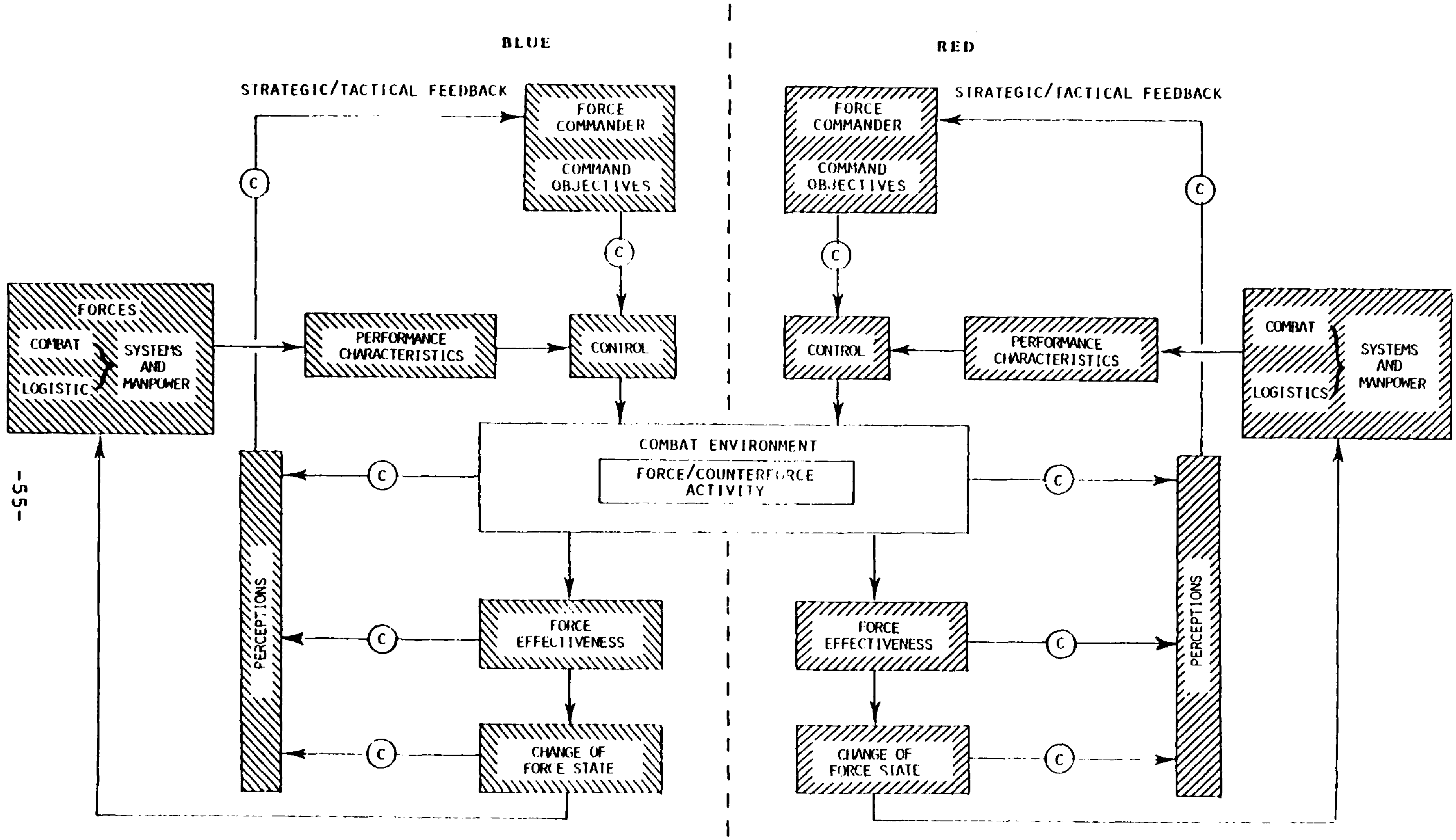


FIGURE 2 TWO-SIDED DYNAMIC FLOW

There must be <u>operations</u> and <u>spatial</u> constraints on the structure of the combat process algorithms. The operations constraints relate to the nature of the military operations that are involved in a particular conflict and the interrelationships among them. The spatial constraints involve the geographical and positional orientation of all significant units engaged in the conflict and their spatial relationships to one another over time. As we consider different levels and types of warfare, the combat process algorithms and their constraints must differ accordingly. It is the differences in process algorithms that are largely responsible for what appear to be gross dissimilarities in models of differing forms of warfare, despite the fact that there may be a large measure of structural commonality among such models. The nature of this structural commonality is of interest in the development of combat theory, as mentioned earlier.

Similarly, despite the symmetry of dynamic flow patterns for Red and Blue in Figure 2, there can be marked asymmetry in the precise form of the operational activities for both sides arising from differences in the combat process algorithms applicable to Red and Blue.

A more detailed examination of combat processes is next in order. The outcome of any combat process (such as force destruction/attrition) is actually a function of the circumstantial combat elements (the inputs, or independent variables of the problem) and of other process outcomes (such as command and control, logistic support, etc.). References 1 and 4 identify the circumstantial elements of combat to be:

- Scenario - Conflict circumstances, initial objectives and missions defined for both sides.
- Environment - Natural and man-made environments in the areas of operations.
- Manpower - Human resources, numerical strengths and characteristics.

- Weapons and Equipment - Material resources,* numbers and characteristics.

- Organization and Structure - Organization and structure of opposing forces.

- Tactics and Doctrine - Tactics, doctrine and operational concepts (both sides).

As observed earlier, the elements of combat listed above represent the inputs to any form of model addressing a specific combat situation. They have been broadly defined and, as they stand, have general applicability to both land and naval warfare.

On the other hand, combat processes (whose "local' outcomes drive the overall outcome in battle), present a somewhat more difficult problem when we seek a single set of definitions that accommodate to the combat and support activities in both types of warfare. Nevertheless, there exists a surprising degree of commonality between the combat processes of land and naval warfare, and it is only in the relative emphases placed on them in the conduct of these forms of warfare, that they may differ somewhat.

The combat processes for land warfare were developed in earlier works[1,4] as the following:

- Attrition
- Suppression
- Movement
- Command and Control
- Communications
- Intelligence
- Combat Support
- Combat Service Support

*All of the equipment and devices for waging and support of war.

These processes reflect a breakdown of combat for analytical purposes based to a large extent on tradition in ground/air combat modeling.

For naval warfare, a similar listing of processes can be developed that is perhaps more attuned to naval terminology and combat experience. This list is as follows:

- Damage and destruction
- Neutralization
- Movement and maneuver
- Command and control
- Communications
- Intelligence
- Cover, deception, and information denial
- Logistic support.

We will not elaborate on these descriptions except to comment that neutralization refers to making a unit militarily ineffective by threatening it through the positioning of superior force or by forcing it to withdraw from a critical area (e.g., the Tirpitz being bottled up in English Channel ports during World War II or, on the other side of the coin, the Graf Spee diverting British warships away from the North Atlantic). We will, instead, develop a list of combat processes that is applicable to both land and naval warfare. The following list suggests itself:

- Force destruction/attrition
- Force neutralization/suppression
- Movement and maneuver
- Command and control
- Communications
- Intelligence
- Force deception
- Logistic support

Any breakdown such as the one above must be somewhat arbitrary. The important thing is that all significant actions , whose outcomes affect overall battle outcome must be included within one or another of the processes listed. It follows, therefore, that, by definition, the list of processes encompasses every kind of action of some importance to combat dynamics.*

The following is a brief discussion of similarities and differences in the processes for land and naval warfare:

1) Force destruction/attrition -- refers to the losses and damage to personnel and materiel. In ground warfare, personnel and unit attrition is directly coupled to measurements of residual force size and assessments of force strength, recognizing, of course, that corresponding materiel losses are also incurred. Attrition or casualty rates for both personnel and materiel are therefore a dominant factor in land warfare modeling. In naval warfare, on the other hand, materiel losses (platforms, sensors, weapon systems) are the paramount consideration in the determination of residual combat power, with attendant losses of personnel occuring in increments of varying size depending on the type of naval vehicle subjected to damage or destruction. In modeling practice, therefore, the destruction/attrition measurable tends to be simplified to combat personnel losses in land warfare and materiel and equipment losses in naval warfare. The former is traditionally treated as a continuous process (as, for example, through the use of some form of Lanchester's equations) whereas in the latter case, the process is highly discrete (as might be characterized by the use of difference equations). Additionally, whenever modeling engagements in naval warfare that involve large, complex platforms such as warships or submarines, one must account for partial disablement or damage to these types of targets that may increase their vulnerability to subsequent attack or may render inoperative certain, but not all, sensors or weapon systems upon which mission accomplishment, in some degree, depends. Such consideration of the

*It can, of course, be argued that a different set of terms would better describe categories of processes. This is granted. The crucial point is the all-inclusiveness of any list of processes.

progressive destruction of equipment is seldom incorporated in the modeling of land combat, even though unit degradation from loss of equipment parallels ship degradation from system losses.

2) Force neutralization/suppression refers to the elimination of a unit or force from active combat (1) by the threat of destruction rather than the direct application of destructive measures; or (2) by negating the effectiveness of forces through manuever, isolation, psychological factors or any other means short of force destruction and attrition. Effectiveness in applying this process depends strongly on psychological and morale factors affecting an adversary. It is probably because of difficulties in modeling these factors that explicit representation of the process is invariably omitted or treated partially in combat modeling efforts, despite recognition of its operational importance. In land warfare, the delivery of suppressive fires that force an enemy to take cover, the capture of enemy personnel and equipment, the bypassing of isolated units, and the negation of unit capability through intimidation all stand as examples of neutralization/suppression. In naval warfare, submarine "hold-down" in ASW or the blocking of a choke point, are examples of neutralization at the tactical level. On a more strategic scale are the barrier or blockade operations, described earlier, that represent a natural extension of the neutralization process.

3) Movement and maneuver refers to the activities that establish spatial relationships among all combat units in warfare. "Movement" is concerned with coarse positioning for the interception -- or evasion -- of enemy forces and for logistic support, whereas "maneuver" addresses the fine tactical positioning necessary for the optimal employment of forces and weapons where making or anticipating contact with an enemy. Movement may be looked upon as the action that places a unit or force in a position to manuever. In land warfare, both are of critical operational importance though they are traditionally modeled in a crude, stylized, fashion, and sometime not at all.* Movement

*Interactive or player-assisted computer gaming probably provides the best structure for incorporating movement and maneuver into combat models.

and maneuver in land warfare can be either strategic or tactical in scope, involving forces at all echelons from theater level down to the smallest tactical units. These activities have direct impact on the ultimate objective of land warfare, that of territorial acquisition. In naval warfare, movement is synonymous with the mobility that permits roving surface, air and undersea forces to make their presence felt over large ocean areas. An expanded view of the movement process might well include transit, but it is perhaps more reasonable and orderly to think of transit as an operation that takes a naval force from some home or forward base to a general operating area, following the dictates of a conflict scenario. Maneuver, on the other hand, relates to the manner of deploying naval weapon platforms in formations or positioning them in end-games for optimal employment of their weapon systems. The increasing reliance on weapons of longer range in naval warfare tends to blur the distinction between movement and maneuver in the modeling of sea control combat.

4) Command and control refers to the processes that govern the hierarchical distribution of command-control authority at all levels of military organizations. This authority carries with it the commensurate responsibility for sound decision-making. The means for arriving at a decision is the commander's estimate of the situation, synonymous with his perceptions of orders of battle, force capabilities and combat activities and outcomes. Decisions are conveyed by directives and orders. A large measure of control is exercised through the medium of recognized tactics and established doctrine.* In land warfare, with the unit of resolution (granularity) smaller than that in naval warfare,** command and control processes are actually more widely distributed and diffused throughout forces of large size and great organizational complexity. In naval warfare, command and control at the weapon systems level is quite highly automated and naval warfare is characterized, as

*See Figure 1 for the relationships among components of command and control and how these, in turn, relate to combat activities.

**This refers to the actual resolution or granularity that exists in real life, not the resolution that any particular model may adopt.

already noted, by a strong technological system (as opposed to behavioral) orientation. Offsetting the possible simplification in the modeling of naval command-control afforded by such characteristics is the relatively heavy reliance placed on "soft kill" measures (i.e., CM/CCM, cover and deception) in naval combat. Modeling the effects of both friendly and enemy use of such measures and how they impact on command and control is an extremely difficult undertaking without resorting to "man-in-the-loop" modeling techniques. With the traditional methods of aggregating forces in models of land combat, there is corresponding aggregation of the command and control structure, resulting in considerable simplification of command-control modeling, the validity of which is thus put in doubt. Aids to combat decision making (e.g., computerized files and analytical programs) are more elaborate and sophisticated in naval warfare where naval ships, for example, can provide the computer capacity, the necessary sources of power and a controlled environment to make possible such support. Despite the better information base and higher computational flexibility available in naval command and control, and tied though it may be to a more compact command structure, it is still difficult to draw general conclusions about the comparative quality and efficacy of command and control in land and naval warfare. In this respect, much depends, as implied in Figure 1, on communications integrity and security and the accuracy of a commander's perceptions of combat activities and outcomes. The modeling of command and control, as it embodies the decision-making function and the choice of engagement tactics is, at present, most successfully treated by having human players interact with computerized land and naval war games.

5) Communications refers to the channels of information flow among units within a military activity and flow from the activity to higher and lower command authority. A functional representation of major categories of communications links involved in combat is shown in Figure 1. These links connect the elements of the "perceptions/command-control" loop shown in the figure and furthermore tie this loop to the activities and outcomes associated with the interaction of opposing forces. In warfare, there are two fundamental types of communications flow within the command structure; a vertical flow for action purposes with

reports traveling up the chain of command and directives coming down, and a lateral information flow to coordinate activities at the various organizational levels. The methods of communication are indeed numerous. They can be oral, written, visual or audio/visual with a wide variety of transmission means from messenger to communication satellites. Voice radio, however, is probably the most prevalent form of inter-unit communication used in combat. In virtually all models of land and naval warfare involving large-scale conflict, the existence and integrity of necessary communications are simply taken for granted. Unfortunately, operational experience will by no means support such an hypothesis, for human communications, under the best of circumstances, are frequently subject to misinterpretation, ambiguity, disruption, and even deception. Superimposing the confusion of combat on an already imperfect process and further adding deliberate attempts by an enemy to destroy or disrupt communications links only increases the uncertainty that communications will be effective when and where they are needed. Current practices in combat modeling fail to reflect these realities.

6) Intelligence refers to the gathering and processing of information concerning enemy order of battle, force movements, deployments, casualties, capabilities, intentions, etc., using all available means and resources whether organic or external to engaged friendly forces. Intelligence information derives from many kinds of operations using many techniques and systems. The processing of intelligence data presents a problem in the conduct of warfare in that delays in data availablility to commanders can range from a few minutes to a matter of several hours. It is from these data, in large measure, that a commander's tide-of-battle perceptions are derived and on these perceptions are based his decisions for future courses of action and the subsequent control over resources that he will exercise. Time lags in data availability along with possible errors in data interpretation can produce considerable disparity between the perceptions and realities of battle. Clearly then, while each of the processes of command, control, communications, and intelligence (C^3I) can, in one sense, be addressed as separate, distinct entities, they are operationally tied together in a highly interdependent manner. Also to be recognized are two parts of the decision-making process involved

in command. One has to do with interpreting the accuracy, timeliness, meaning, and significance of intelligence data in order to arrive at an estimate of the enemy condition; the other concerns the selection of some particular course of action next to be taken, from among a set of possible alternatives. As already noted, decision-making can be reasonably accommodated in combat modeling by the employment of "man-in-the-loop" techniques. This, however, is generally neglected in land and naval warfare modeling, where, with very few exceptions, there is an implied assumption that perfect information is available at command levels on both sides. A comparison of intelligence modeling requirements in land and naval warfare suggests that the naval problem should be simpler because of the concentration of force into fewer discrete elements (i.e., ships, submarines), the technically easier problem of acquiring naval surface targets, the reduced "fog" of battle, and the more modest geographical expanse, in general, of naval combat engagements. On the other hand, naval battles are of short duration and high intensity, requiring the rapid exercise of command, and engagements are at relatively long ranges, making the assessment of damage to the enemy both difficult and uncertain without recourse to reconaissance or surveillance means. Such factors underscore the criticality of intelligence information in naval warfare, as difficult as the modeling of the intelligence process may be.

7) Force Deception refers to employing all manner of tactics and devices to deceive, surprise and confuse an enemy largely by confounding his intelligence processes. Deception exploits what are referred to as "soft-kill" techniques. Specifically excluded from this process are passive countermeasures that utilize various forms of radiation from enemy targets to home in on a target and destroy it. Such countermeasures are members of the class of "hard-kill" systems that contribute to the process of force destruction. Deception tactics and devices are intended to interfere with, disrupt and confuse human sensing and the diverse man-made sensing systems used to detect, locate and track an enemy in space, in the atmosphere, on the earth's surface or beneath the seas. They are also designed to prevent the clear transmission of information and directives via communcations

links. Deception systems, like countermeasure systems, operate over large parts of the electromagnetic and sound spectra. They include the use of camouflage, smoke, cloud, terrain masking, electromagnetic and acoustic noise and deception jammers, and decoy devices of many kinds and of widely varying degrees of sophistication. They also involve planned misinformation of many kinds and feints. As noted earlier, heavy reliance must be placed on deception techniques in naval warfare. This can be attributed to the limitations that far-ranging mobility places on carrying adequate "hard-kill" resources to counter a determined enemy who, in certain areas of the world, can concentrate his forces in sufficient strength to saturate or overwhelm a naval force. Such constraints are less frequently encountered in land warfare where the heavier emphasis in battle is on firepower, hence "hard-kill", and the replenishment of ammunition and other resources occurs in a more continuous fashion. Needless to say, modeling of the force deception process is a distinctly two-sided affair that is highly stochastic. It is inordinately difficult, if not impossible to perform such modeling in automated gaming fashion but instead, as with the other socio-technical processes, such as command-control, communications and intelligence, can best be handled by placing humans in the computer gaming loop. Adding to these difficulties is another factor relating to the efficacy of deception techniques -- that of employment frequency. What may well deceive or confuse an enemy the first time it is used, may fail to do so with subsequent usage. Little in the way of hard data relating to these phenomena is available. Rather, the effects of deception devices are still the subject of advanced, difficult experimentation or else are highly conjectural. It is perhaps because of this and the other reasons stated that so little has been accomplished with the explicit modeling of deception in either land or naval warfare. The fact remains, however, that it is important, particularly in the case of naval warfare and, furthermore, is strongly interactive with all the elements of command-control and intelligence. Most unfortunately, the behavioral aspects of warfare embodied in the C^3I and deception processes, since they involve the human capacity for discernment and reaction, are far and away the most troublesome of all to treat algorithmically in modelings. Introduction of "man-in-the-loop" techniques referred to several times above, is not without its difficulties in

that one faces the problem of great variability in the outcome of man-machine interactive games as the human game players change. Even as the solution to this modeling dilemma continues to elude us, it is important that we recognize how much of the combat modeling problem we are not able to address satisfactorily at the present time.

8) Logistics Support refers to the act of providing primary sources of manpower, transportation, human resources, equipment, provisions, ammunition, fuel, spares and other materiel to combat forces. The logistics support process further encompasses all construction, engineering, repair, facilities support and other services required by the combat forces. In land warfare at theater level, the logistics support process is vast and complex, incorporating the entire problem of sea control, where necessary, to support air and ground forces that are fighting overseas. The sea control aspect of theater-level logistic support subsumes a smaller, independent, virtually self-contained naval logistics system that is critical to the staying power of deployed naval units. Hence the defense of naval forward bases, their sea and air supply lines, and the replenishment ships that support the carrier battle groups, is of vital importance to land battle logistic support. The logistics support process for naval warfare would normally include consideration of the above factors. Little has been done in the modeling of theater-level conflict to tie the ground/air war into the extensive cross-ocean logistics support that such conflict entails. Thus, the sea control mission is usually modeled independently without particular regard for land battle activities and outcomes. Land warfare, on the other hand, is generally modeled with little concern for intertheater logistic constraints. A model coupling these two large pieces of the logistics problem, wherein the course and pace of the land war establishes logistics requirements and the naval war and sea lift capabilities are determining factors that may affect the course and pace of the land war, would afford a better overall understanding of the logistics process and its impact on ground/air operations. Of equal importance in such an undertaking is the light it may shed on preferred strategies for conduct of the sea war based on land warfare outcomes.

Having discussed combat processes at some length, it is now appropriate to consider briefly the subject of combat functions. Rather than attempt an exhaustive listing of all the functions that might conceivably relate to each of the processes listed above, some examples are presented in Table III that are indicative of the types and levels of activity that should be involved implicitly or explictly in the development of process algorithms. Each of the functions identified can be further broken down into lesser activities which can be termed "action events". In addressing the hierarchy of "processes-functions-action events," we are dealing with a structure of activities from which can be drawn specifications to guide combat modeling in general and land and naval warfare modeling in particular. At the lowest level of this hierarchy (action events), we are involved conceptually with the simplest of activities such as receipt of a message, a binocular scan, or the depression of a firing button. These are matters that are beyond our concern in this paper.

Needless to say, not all of the illustrative functions in Table III need be modeled explicitly nor would it be practical to try to do so. It is essential, however, to recognize in any model the functions that are adequately simulated and those that are not.

A cursory examination of the "functions" level of the hierarchy makes apparent a crucial point: the interdependence of the eight combat processes. It can be seen, for example, that the influence of command-control and communications is distributed, in some degree, throughout virtually all of the processes listed, while the processes of movement and maneuver and of intelligence influence and, in turn, are influenced by force destruction/attrition, force neutralization/suppression and other processes. In short, each combat process depends to a varying degree on all others. Coupling may be particularly strong in some cases, whereas in other instances it may be weak. In short, combat processes cannot be treated as being independent of each other, and algorithms for combat processes cannot be assumed to be mathematically independent functions.

Table III

COMBAT PROCESSES AND ILLUSTRATIVE RELATED COMBAT FUNCTIONS

- Force Destruction/Attrition
  - Search and reconnaissance
  - Target detection/acquisition/classification
  - Weapons designation and allocation
  - Target track/localization
  - Weapon platform/positioning
  - Weapon launch and control
  - Target intercept
  - Kill/damage assessment
  - Inter/intra unit communications
  - Fire planning and coordination

- Force Neutralization/Suppression
  - Target detection/classification
  - Target area designation
  - Weapons designation and allocation
  - Weapon launch and control
  - Area surveillance/suppression assessment
  - Target surveillance/neutralization assessment
  - Maneuver planning
  - Psychological war action

- Movement and Maneuver
  - Route surveillance
  - POL consumption planning
  - Position location
  - Navigation
  - Route selection/optimization
  - Use of terrain/weather masking
  - Obstacle breaching/avoidance
  - Inter/intra unit communications
  - En route security

- Command and Control
  - Estimate of situation
  - Decision aids employment
  - Decision-making
  - Directives/and orders

- Communications
  - Maintaining inter/intra unit links (up, down, and laterally)
  - Maintaining intra-unit links
  - Communication security
  - Traffic prioritization

- Intelligence
  - Intelligence collection
  - Intelligence processing
  - Covert actions (espionage)
  - Electronic/optical/acoustic reconnaissance
  - Electronic/optical/acoustic surveillance
  - Intelligence processing
  - Inter/intra intelligence dissemination

- Force Deception
  - Electronic countermeasures
  - Acoustic countermeasures
  - Camouflage
  - Decoy employment
  - Terrain/weather masking
  - Feints
  - Misinformation dissemination

- Logistics Support
  - Manpower/material basing
  - Transit
  - Maintaining ground, air, sea LOC
  - Underway replenishment
  - Material stockpiling
  - Battlefield equipment recovery
  - Repair and maintenance
  - Construction
  - Communications equipment
  - POL supplies
  - Food supplies
  - Housing and shelter
  - Medical support

Therefore, we find that while it may be convenient to think of combat as the dynamic relationship of a set of combat processes, each of which is comprised of many subordinate combat functions, we cannot, in a strict sense, model combat in pure analytical or mathematical form because of coupling among the processes. Only if we are willing to disregard, or accommodate in highly implicit fashion all but the most dominant of inter-process couplings, could we ever hope to address the combat modeling problem in this fashion. Instead, recourse to simulation techniques is the traditional way in which such problems are solved. Even so, as observed in previous discussion, there are some important aspects of combat that are simply not amenable to simulation within the current state of the art.

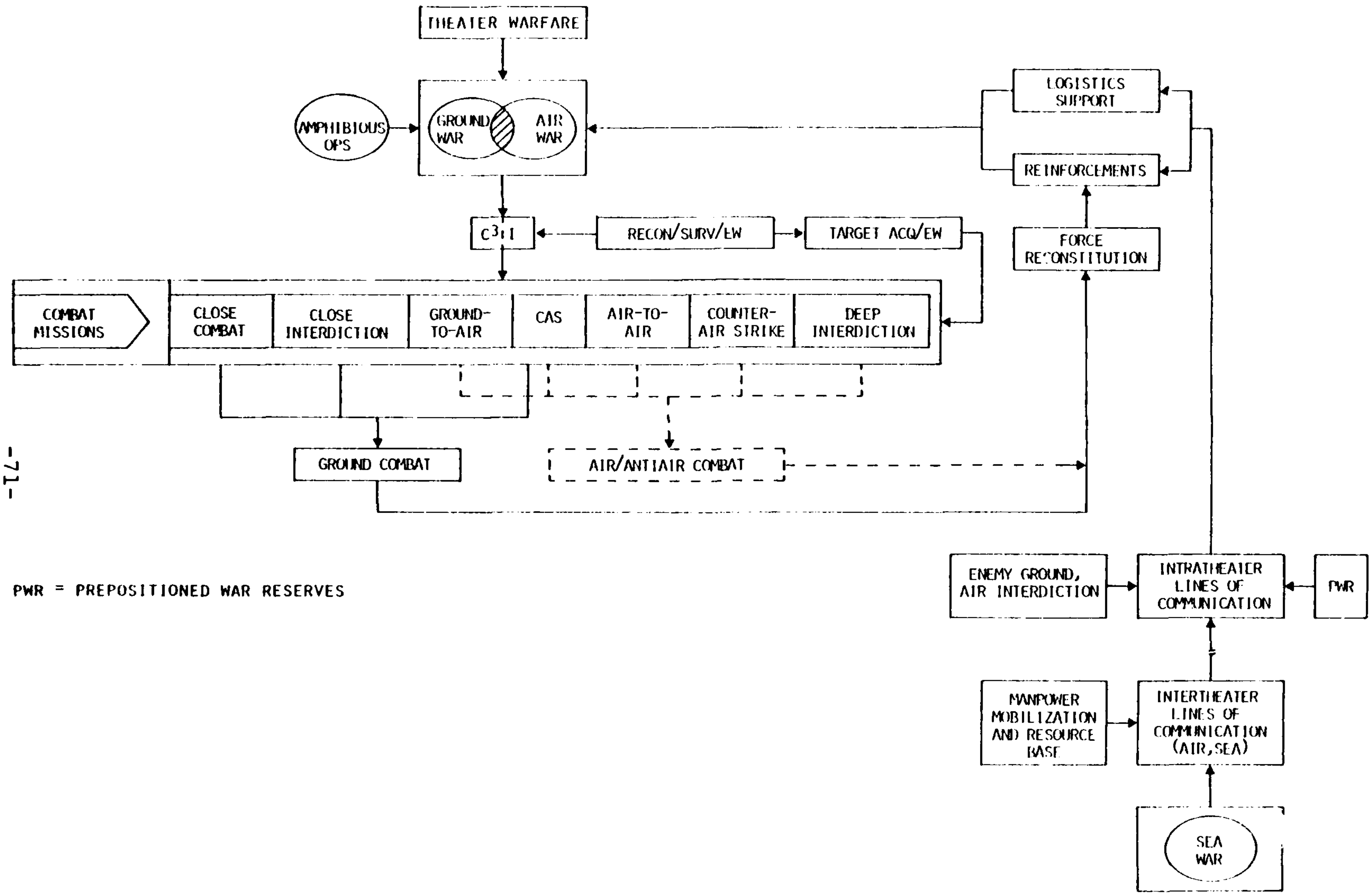
In land warfare, the inter-process coupling effects are strong, but not always recognized as such because of heavy emphasis placed (albeit erroneously) on firepower and attrition (i.e., the force destruction process) at the expense of other processes. This, when combined with force aggregation principles normally used in land combat modeling, tends to suppress the true import, or even the very presence in models, of some of the more troublesome combat processes that are strongly dependent on human behavior. In naval warfare, because of the discrete accountability for ships, aircraft, submarines and their weapons and sensors, the explicit modeling of these elements is feasible and called for down to the level of combat functions (small model granularity). And while an emphasis properly belongs on force destruction in naval warfare, one cannot afford to downplay or overlook the force deception process, as difficult as the modeling of it may be. Since naval warfare is conducted by assembling relatively small numbers of complex vehicles into mission-oriented task forces of various kinds, it develops that a hierarchical gaming structure of the one-on-one, few-on-few, force-on-force variety is suited to modeling sea control combat, certainly more so than in the case of land warfare. The only

proviso is that a library of modeling results covering a sufficient number of tactical variations be developed at the lower levels of the hierarchy in order to ensure reasonable tactical fidelity and consistency when forces are aggregated to the next highest level.

The combat process algorithms referred to throughout this paper, though in many cases more conceptual than realizable, must contain appropriate representation of factors pertaining to unit kinetics (velocity, acceleration), range, altitude and depth. Many of these, such as maximum weapon or sensor ranges, weapon and aircraft velocities, aircraft rates-of-climb, service ceiling, can be defined by the elements of combat (i.e., the inputs to the model). Many others are combat event-dependent, such as unit rates of advance or line-of-sight limitations for a unit at some point in time. It is by incorporating such quantifiable time and space factors into the process algorithms that the spatial relations and constraints are accommodated in the modeling process in order to account for absolute and relative positioning of all units engaged in battle as a function of time.

Lastly, there are operational constraints that directly affect and bound the form and structure of the process algorithms. These constraints reflect the nature, magnitude and limitations of the overall operation, specifically identifying those components of the operation that are to be modeled. Of great importance is the definition of how all the operational components relate to, or interact with one another. This can best be illustrated by operations diagrams of the type shown in Figures 3 and 4 for theater and sea control operations respectively.

Briefly, Figure 3 depicts in summary fashion the ground/air war operations of a theater-level conflict and refers to the sea war that is fought to maintain the integrity of the logistic lines of communication supporting the land campaign. The sea war also may include the force projection mission or the provision



PWR = PREPOSITIONED WAR RESERVES

FIGURE 3 THEATER WARFARE OPERATIONS

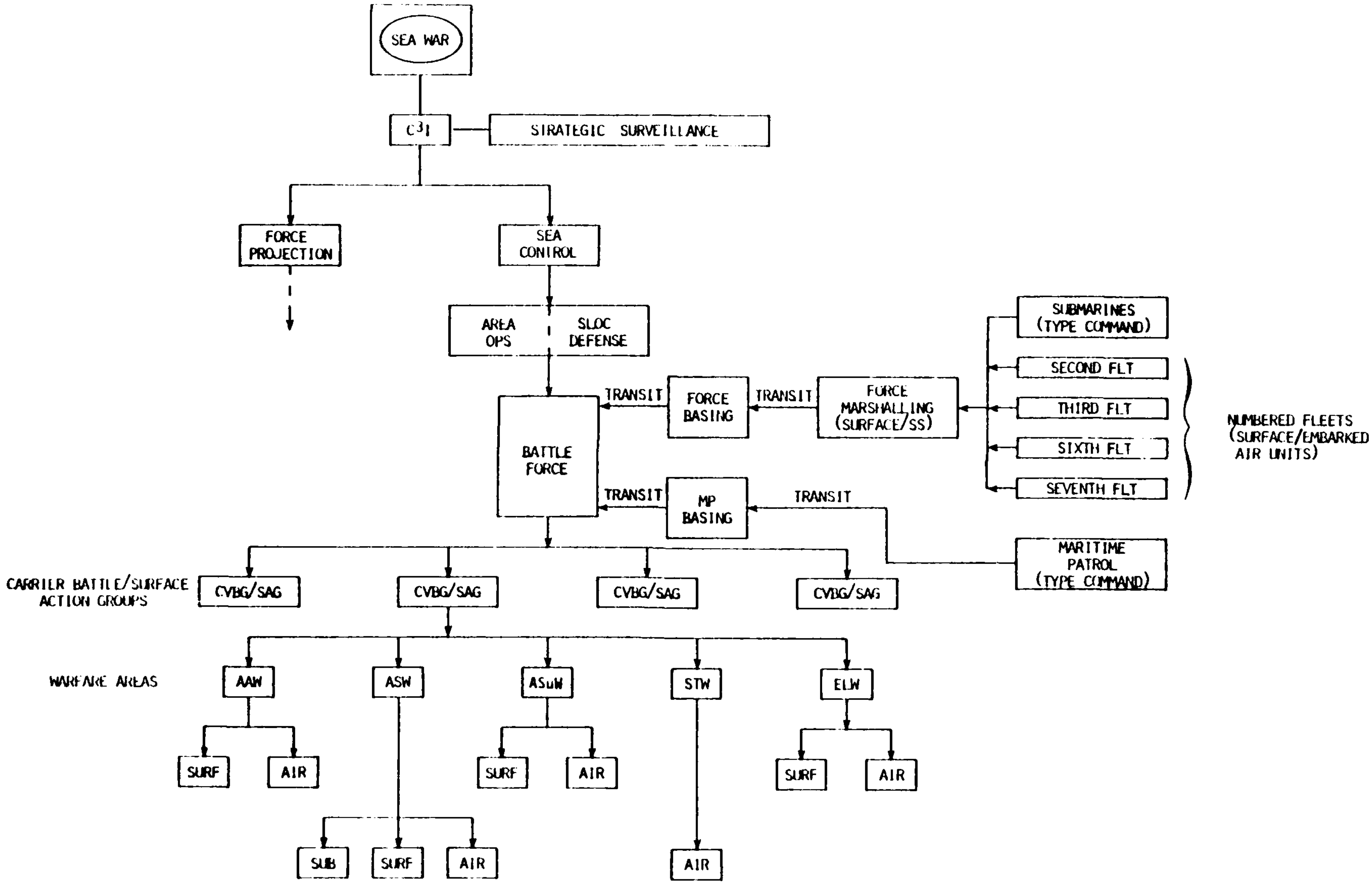


FIGURE 4 SEA CONTROL OPERATIONS

of air support to the ground forces, although this is not shown in Figure 3. In Figure 4, the sea war referred to in Figure 3 is expanded to a level of detail comparable to the land war representation. Figure 4 illustrates the marshalling of surface and air units from the numbered fleets, supported by submarines and maritime patrol aircraft to form a battle force that will operate over some specified ocean area with a particular assigned mission. The force consists of several carrier battle groups and surface action groups which, depending on threat and circumstances defined by the scenario, will engage in any or all of anti-air, antisumbmarine, antisurface, strike and electronic warfare. These operations are conducted by ships, aircraft and submarines, as the figure indicates. It should be pointed out that the structure of C^3I, is hierarchical down to the individual combat unit level, despite the fact that it is shown only by a single block near the top of Figure 4. Logistics support largely derives from forward basing, from replenishment ships that operate with the battle groups and from separate underway replenishment groups that rendezvous with surface combat forces.

Both Figures 3 and 4 can, of course, be further broken down in greater detail to ultimately include, for example, tactical battlefield force disposition diagrams for land warfare and battle group formation diagrams for naval warfare. While such levels of detail must invariably be addressed in combat modeling, they transcend an intent that the figures present only some of the more fundamental operations for illustrative purposes.

In summary, this section advances an hypothesis that combat modeling -- and perhaps more significantly, combat itself -- can be thought of qualitatively as the strong dynamic interaction of three fundamental activity loops: (1) combat force engagement, (2) perceptions, command decisions and resource control, and (3) logistics. This interactive dynamic structure (Figure 1) has been shown to be invariant with type and level of warfare activity.

The first quantitative aspects of modeling are introduced by the concept of combat processes that consist of a set (eight in number) of generalized, fundamental military activities whose local outcomes are deemed to have direct, first order effects on overall conflict outcome. These processes come into play at specific locations in the dynamic structure of the model and are thought of as algorithms (hence the quantitative components of the model), possessing the following characteristics:

- They functionally relate outcomes of combat processes (the dependent variables) to both the elements of combat (the independent variables or inputs) and to other process outcomes (process "coupling").
- They include in their formulation the proper accommodation of all spatial relationships, spatial constraints and rates of change.
- They faithfully adhere to and are consistent with the military operations that the combat model purports to represent.

Even though a generalized set of combat processes can be defined that apply to all forms of warfare (land, sea, air), it is in the process algorithms themselves that marked changes occur with differing forms of warfare. These changes can be attributed in large measure to the differing nature of associated operations which, in turn, stem from differing geophysical and operational environments.

This combination of a fixed dynamic structure and variable process algorithms does indeed afford a mathematical description of military activities conducted in time and space. Despite the fact that "process coupling" inhibits the mathematical modeling of combat and that certain process algorithms stand in need of further substantial development, the combat model structure described in this paper allows us to contrast the modeling of different forms of warfare and hopefully promotes a better understanding of warfare in general.

SUMMARY OF CONTRASTS IN MODELING AND NAVAL WARFARE

The following represents a collection of summarized observations that are derived from the "top-down" examination of land and sea combat modeling described in this paper:

- There exists a commonality in basic missions for land/air forces and for sea control forces: that of exercising control over geographical areas of interest. The means of exercising control in both instances is through the application of superior military force or the threat of such application. Distinct disparities in the nature of land and sea war, on the other hand, arise from sharp differences in respective geophysical environments, and hence in the operations environments.

- The principles of warfare enunciated for land combat, though not authoritatively definitized in explicit form for sea combat, are nonetheless applicable to both. Model design should serve these principles to the extent feasible, but in no instance should the principles be violated. The principles serve as useful qualitative measures by which models can be assessed and model results interpreted.

- The outcome of a theater land campaign can be significantly influenced by the particular naval strategies adopted by both sides in a conflict. The priorities of naval engagement and destructive measures to be taken by each side should be established on the basis of land war objectives. This calls for coupling the sea war to the land/air war in modeling.

- The asymmetry in U.S. and Soviet naval objectives (sea control for the former versus sea denial for the latter) affects the value placed by each side on its combat resources. The U.S. may be obliged to conserve naval resources for other missions that exploit the attainment of sea control, such as power projection. The Soviets for the present do not have this concern to the same degree. This is a non-zero sum game in game-theoretic terms and, in modeling, implies certain asymmetries in risk-taking and force commitment doctrine for both sides.

- Land and naval warfare modeling must reflect the numerous significant asymmetries in U.S./NATO and Soviet/Warsaw Pact doctrine, tactics and weaponry. The tendency to "mirror-image", especially in doctrine and tactics, is common and dangerous.

- Territorial gain is a prime measure of merit that relates directly to the accomplishment of objectives in land warfare. Successful execution of the movement and maneuver process contributes directly to territorial gain. Extensive movement and maneuver, furthermore, often results when high, favorable casualty ratios (relating to the force destruction/attrition processes for both sides) are experienced in action against an enemy. However, there are numerous instances when movement and maneuver are achieved without the attainment of high casualty ratios. In such cases, the results may evolve from effective use of the force neutralization/suppression process. Thus, while correlation of movement and maneuver (and hence territorial gain) with only the force destruction/attrition process can be open to question, its correlation with some combination of destruction/attrition and neutralization/suppression should prove to be more valid and useful. Unfortunately, emphasis on attrition as the measure of merit has been traditional in land combat modeling, rather than emphasis on territorial gain. This is not realistic and can produce model results that are deceptive and misleading.

- Force destruction/attrition is a measure of merit that is directly -- and properly -- applicable in the general case to the mission of sea control. A combination of force destruction/attrition and force neutralization/suppression constitutes an even more complete and valid measure of merit for sea control combat.

- Greater predictability of battle progression is assumed in the modeling of land warfare at the theater-level, despite the fact that land combat is structurally more complex than sea control warfare from an overall viewpoint of activity diversity, interactions and scope. Conversely, the nature of naval encounters and the duration and intensity of naval engagements make the modeling of sea control combat more strongly scenario-dependent. These modeling practices derive in large measure from the differing nature of actual combat operations in each instance. Naval warfare involves extended

periods of time in transit or on station for naval units with sporadic contact with the enemy and short periods of concentrated combat activity. In land warfare, contact between opposing forces is relatively prolonged and combat activity more protracted.

- Naval warfare is more ideally suited than land warfare to a hierarchical approach in modeling (a series of separate, but interfacing models that range from "one-on-one" to "force-on-force"). An essential factor, however, is the availability of an adequate library of engagement results incorporating varying attack modes, tactics and weaponry that ensures tactical and systems consistency when interfacing with models of higher aggregation.

- The military, political and psychological impact of nuclear and chemical weapons is more prevasive and severe in land warfare than in naval warfare. This may, in fact, favor the less inhibited use of unconventional weapons in the naval warfare environment.

- The unit of resolution (smallest unit that can "shoot, move, communicate") is very much smaller in land warfare than in naval warfare. In naval warfare, the unit of resolution is normally a ship, submarine or aircraft, whereas in land warfare, it is the squad, or platoon, and, in the limit, can be an individual soldier. The practice of force aggregation in land combat modeling represents a significant departure from the realities of human behavior in the conduct of such warfare. In naval warfare, a total force is divided into a relatively small number of larger manpower increments. These must be treated as discrete units in modeling, but as such, more closely conform to the behavioral realities of naval combat.

- Combat processes such as force destruction/attrition, movement and maneuver, and force deception should be handled as highly discrete activities in naval warfare modeling, whereas with reasonable validity, they can be treated as relatively aggregated, continuous phenomena in models of land combat.

- The partial destruction or disablement of major naval combatants is an important consideration in naval warfare models because of their limited number and the design ard operational emphasis

placed on their survivability through damage control techniques. In land warfare modeling, the counterpart to partial destruction and disablement is of a more aggregated nature concerned with erosion of force capability due to attrition. Such erosion, while usually focussed on losses of combat personnel, also is affected by losses of material and equipment, which are accounted for in models by various methods of aggregation.

- Major naval weapons are complex, lethal and battle-limited in number (they cannot be replenished during an engagement). It is, therefore, important that they be accounted for in modeling on a round-by-round basis. This, in turn, implies explicit modeling of naval weapon systems and the sensors on which they depend. The multiplicity of smaller weapons contributing to firepower in land warfare allows for considerable aggregation in the modeling of weapon effects.

- No resupply or reinforcement can be routinely provided to naval forces during engagements. Replenishment for naval units generally occurs either while in transit or in port, giving the naval logistics support process an aperiodic, discrete character that can be reflected in naval campaign modeling. In land warfare, the logistics process is geographically and operationally more complex. In the aggregate, however, it takes on continuous properties to a greater degree than is realized in naval warfare. The immensity of the system may in some measure alleviate the short-term criticality of logistic shortfalls, but at the same time, modeling logistic support in the aggregate can mask perturbations that in reality are crucial. The complete, longer-term effects of small but critical shortcomings on combat effectiveness have yet to be adequately modeled in land warfare and sometimes even the effects of gross shortcomings in logistics are ignored.

- The command and control process is more diffuse in land warfare than in naval warfare. This is because of the many echelons of command and the multiplicity of units of resolution spread laterally and in depth in land combat. The normal practice of aggregating forces in land combat modeling results in corresponding aggregation of the command and control structure, causing departures from reality of unknown magnitude. In naval warfare, command and control is more technically

complex and sophisticated, more clearly local and direct in its application, and more highly automated at the weapons systems level. Its vulnerability and criticality are accordingly greater, and aggregation of naval command and control in modeling is more suspect.

- A preferred technique for representing the command and control process in both land and naval warfare modeling is to incorporate a "man-in-the-loop" by having human participants play the command role in man-machine interactive games. Such techniques, however, can sharply reduce outcome reproducibility as the participants change.

- Perceptions of prevailing combat activity and of the status of forces (both friendly and enemy) are absolutely critical to the command and control process yet are rarely represented in either land or naval combat modeling. Correct perceptions are probably more difficult to achieve in land warfare than naval warfare because the ubiquitous "fog of battle" is more pronounced and harder to penetrate in the case of the former. As the prelude to command decision making, the formation of perceptions by a commander and his staff attempts to account for the multiplicity of uncertainties inherent in combat, and is dependent upon a synthesis of earlier perceptions modified by the flow of information on the status of friendly and enemy forces.

- The force deception process is in general more decisively critical to naval warfare because of potential enemy capability to saturate "hard kill" weapon systems that are constrained in number and ammunition supply. The modeling of this process is difficult to achieve because of strong behavioral components upon which its efficacy depends. It is best accommodated by two sided, "man-in-the-loop" gaming.

- In broadest terms, a combat model is concerned with the representation of combat activities in time and space. It has been determined that such a model can be treated as:

  - a structurally invariant dynamic interaction, for all types and levels of warfare, of three fundamental activity loops: (1) combat force engagement, (2) perceptions, command decisions and resource control and (3) logistics.

- an invariant set of eight process outcomes which are (by definition) inclusive of all combat actions and upon which the overall conflict outcome depends. These are: (1) force destruction/attrition, (2) force neutralization/suppression, (3) movement and maneuver, (4) command and control, (5) communications, (6) intelligence, (7) force deception and (8) logistic support. The processes come into play at specific points in the model dynamic structure and are thought of as algorithms that: (1) relate a particular process outcome to the model inputs and to the outcomes of other processes, as appropriate, (2) reflect in their formulation, the spatial relationships and constraints pertaining to all force units and systems engaged and (3) are representative and consistent with the structure of operations being conducted in the conflict.

It is in the expressions for the various process algorithms that models for varying types and levels of warfare can differ widely. Furthermore, these algorithms can, and generally should be, different for the attacker and defender in a conflict situation.

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